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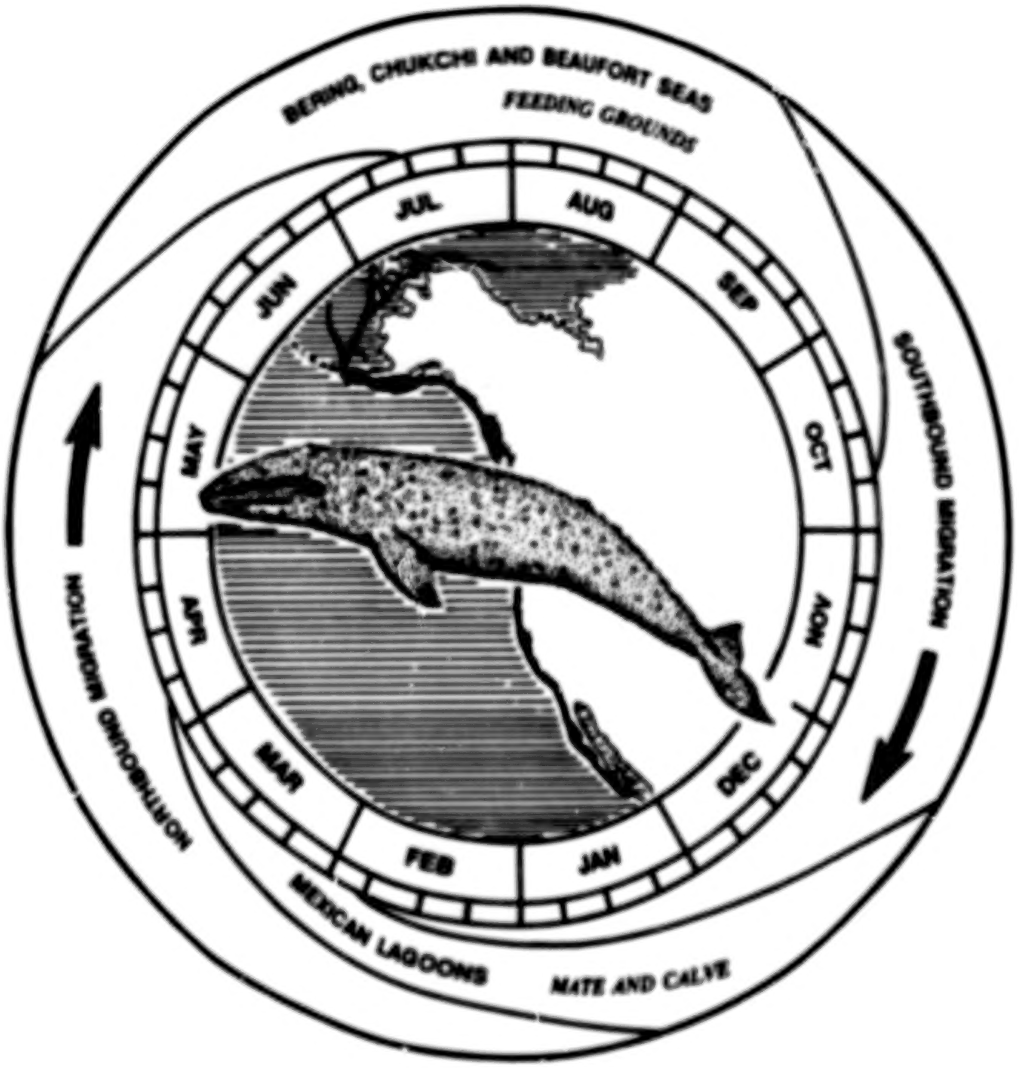
GRAY WHALE MONITORING STUDY
Final Report



August 1989

MMS
U.S. Department of the Interior
Minerals Management Service
Pacific OCS Region

GRAY WHALE MONITORING STUDY

Final Report

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ERRATA SHEET

1) Contents, p. v should read as follows:

SHOREBASED SURVEYS OF THE NORTHBOUND MIGRATION 58
PHASE A NORTHBOUND MIGRATION 59
AERIAL SURVEYS 59
Abundance 59
Migration Corridors 62
Direction of Movement 62
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2) p. 53: Table 10 should be replaced with table at right:

Table 10. Mean distance of southbound gray whales by pod size, shorebased observations, January 1987.

	Distance from Shore (km)	
Pod Size	No. of Pods	Mean ± S.D.
1	24	3.4 ± 2.4
2	13	3.2 ± 2.1
3	12	5.2 ± 3.1
4	1	5.7 -
5	1	10.1 -
Non-Cow/Calves	51	4.0 ± 2.7
Cow/Calves	3	1.8 ± 0.2
Total	54	3.8 ± 2.7

3) p. 59, para. 8: Figures 22 and 23 should read Figures 20 and 21.

4) p. 63, para. 6: Figures 20 and 23 should read Figures 20 and 21.

5) p. 66, para. 2: Figure 24 should read Figure 22.

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EXECUTIVE SUMMARY

OBJECTIVES

The Minerals Management Service (MMS) contracted MBC Applied Environmental Sciences to address concerns that the cumulative effects of oil and gas development activities in the Pacific Outer Continental Shelf (POCS) region may have an adverse impact on the behavior and traditional migration routes of the gray whale (*Eschrichtius robustus*).

The study's objectives were: 1) to conduct a literature review of gray whale migratory behavior and 2) to monitor gray whale behavior and determine the distance they travel from shore before and after placement of an OCS production platform in the northern Santa Maria Basin. The first federal oil and gas producing platform (Julius) is planned for installation in Lease Block P-409, 15.3 km offshore Point Sal, Santa Barbara County, California. Due to indefinite delays for platform installation, the study design was modified to include only pre-platform installation studies.

LITERATURE REVIEW

Published and unpublished literature on gray whale natural history along the migratory pathway between Alaska and Baja California was reviewed. Over 100 references were summarized to provide a general synopsis of population estimates, migratory behavior, and ecological information, which is provided as Section I of this report.

FIELD SURVEYS

Field studies were conducted during the southbound migration in January 1987 and during the northbound migration in April-May 1986, March-April 1987, and March-April 1988. Most aerial observations were conducted along north-south transects from 3.2 to 32 km offshore; shore observations were conducted from Point Sal and Mussel Point.

Aerial transects were flown in a single-engine, high-wing aircraft. These surveys provided data on the numbers and course headings of whales in the offshore portion of the study area, outside the viewing range of shore-based observers. Observers on shore used binoculars and surveying equipment (theodolites) to record gray whale behavior and track their movements. Raw data were analyzed to estimate abundances, the width of the migratory corridor, direction of movement, dive duration, respiration rates, and social and surface active behaviors during each survey and migratory phase.

RESULTS

GRAY WHALE ABUNDANCE AND MIGRATION TIMING

The majority of the 21,000 gray whales that migrate annually between summer feeding grounds in the Arctic and winter calving lagoons in Baja California are expected to pass through the Inner Santa Maria Basin, some through Lease Block P-409. Gray whales probably occur in the area for at least six months, between December and May of each year.

Southbound gray whales are expected to occur between December and February with peak numbers in mid-January. Although previous observations have documented temporal pulses of individuals by age, sex, and reproductive status, these groups overlap, particularly during peak migratory periods. There is also increasing evidence that full-term calves are born north of the Santa Maria Basin during the southbound migration. Eight southbound cow/calf pairs were observed during the present study.

Northbound gray whales also exhibit temporal pulses by age, sex, and reproductive status. The first northbound pulse (Phase A) arrives in central California as early as late February or early March and includes only non-cow/calf animals. Peak numbers pass through the area between March and April. The second pulse of northbound migrants (Phase B) includes cows and their young-of-the-year calves. The majority of these cow/calf pairs will pass through the area between April and May each year. Phase B peaks are not as distinct as those for non-cow/calves.

GRAY WHALE MIGRATION CORRIDORS

The results of aerial surveys indicate that the migratory corridor of gray whales at Point Sal extends offshore to at least 33 km, over the continental slope at water depths of 200 to 400 m. Most gray whales, however, are found within 24 km of shore, over mainland shelf waters less than 200 m deep; water depth may limit their seaward distribution.

Platform Julius is to be located 15 km offshore and within the gray whale migratory corridor. It will be 1 to 3 km east (inshore) of the center of the southbound, non-cow/calf migration route and about 1 km west (seaward) of the center of the northbound migratory route of non-cow/calves. Because northbound cow/calves travel close to shore (mean of 0.4 km from shore) few calves will be in the vicinity of the platform. However, between Point Sal and the Santa Maria River, there is the potential for short-term stress to cow/calf pairs if pipeline construction is conducted during the Phase B migration.

Gray whale migration patterns in the study area appear to be influenced by coastal physiography and bathymetry. Both southbound and northbound non-cow/calves migrate offshore and across local embayments, as if following depth contours. Northbound non-cow/calves traveled about 3 km closer to shore than southbound non-cow/calves, although the seaward limits of the two migration corridors were similar.

Most northbound cow/calf pairs follow the coastline, generally within 2 km of shore, although some travel the offshore pathway of non-cow/calves. Most non-cow/calf pods were seen during March surveys and cow/calf pairs during April and May. Mean pod size increased with distance offshore during both the southbound and the northbound, Phase A migrations.

COMPARISONS WITH OTHER STUDIES

Characteristics of the gray whale migration at Point Sal were compared to those at the Channel Islands National Marine Sanctuary, and along the central California coastline, at Granite Canyon and Yankee Point. Although different field techniques and the timing of the studies may have affected the comparison, two general patterns emerged.

The density of both non-cow/calves and cow/calves (as determined in aerial surveys) in the open waters of the Santa Maria Basin off Point Sal were similar to the density of non-cow/calves in open waters around the Channel Islands. However, greater densities of cow/calves were observed in nearshore waters of the Channel Islands than in the open waters or channels between the islands. Recent evidence indicates that some southbound cow/calves "stack up" in the nearshore of the Channel Islands waters before moving south through the Southern California Bight.

The gray whale migration corridor is substantially wider in the Santa Maria Basin than along the coast from Granite Canyon to Yankee Point and corresponds to the width of the continental shelf in those two different areas. Gray whales appear to migrate primarily at water depths of 100 to 200 m, suggesting that water depth may be the major factor that determines the outer limit of the gray whale migration corridor.

MIGRATORY BEHAVIORS

Swimming Speeds

Northbound gray whales generally travel slower than southbound gray whales, and they apparently accelerate their rate of travel as they move north. The slower rate in the southern part of the range may result from behavior such as nursing and mating.

Previous studies along the Pacific Coast have indicated that southbound gray whales swim at 5 to 10 km/hr; there appears to be little variation between daytime and nighttime rates. At Point Sal southbound non-cow/calves averaged 7.2 km/hr, whereas northbound non-cow/calves averaged 5.1 km/hr. Both northbound and southbound cow/calf pairs traveled somewhat slower, however, at rates of about 5.0 km/hr.

Dive Duration

The diving and surfacing patterns of gray whales near Point Sal included: 1) a long dive (>1.0 min) followed by several dives less than 1.0 min; 2) regular long dives >1.0 min; and 3) irregular or unpatterned dives. Both southbound and northbound whales exhibited these patterns.

Southbound non-cow/calves averaged 0.5 min for short dive times (<1.0 min); 4.0 min for dives between 1 and 10 min; and 2.5 min for all dives combined. Cow/calf pairs exhibited slightly shorter average dives in all three categories.

The dive duration of southbound gray whales was inversely correlated to pod size and the dive times of single whales were significantly longer than those of pods of two or more animals. However, this may be an artifact of sampling, since there was seldom any way to identify individuals in a pod.

The dive duration of northbound non-cow/calves was also inversely correlated with pod size and the dive times of single animals were also significantly longer than those of pods containing two or more animals. Northbound non-cow/calves averaged 0.5 min for short dives; 4.0 min for long dives; and 2.4 min for all dives.

Cow/calf pairs exhibited longer short dives (0.5 min), shorter long dives (3.2 min.), and shorter overall dive times (2.4 min) than non-cow/calf pairs. These differences may reflect a defensive mechanism to avoid detection by predators or the inability of calves to make long dives.

Respiration Rates

Southbound non-cow/calves averaged 21.3 blows/hr and southbound cow/calves averaged 18.5 blows/hr. These rates are comparable to those of southbound animals near Soberanes Point in central California.

Northbound non-cow/calves averaged 21.0 blows/hr, whereas cow/calves breathed more often, averaging 29.6 blows/hr. The faster breathing rates of cow/calves may reflect higher metabolic requirements of the calves or simply their inability to make extended dives.

Other Behaviors

While swimming speeds, dive durations, and respiration rates were subject to quantitative analyses, other types of behavior -- social and surface active behavior -- were only quantified according to type and frequency of occurrence. Therefore, the data are of limited usefulness in comparing pre- and post-operational behavior.

Most surface and social behaviors occur while the animals are milling, and the amount of milling varied widely according to the migration or phase. During the southbound migration, 2.9% of all pods milled; during the non-cow/calf northbound migration, 12.4% of all pods milled; and during the cow/calf migration, 30% of the pods milled. While traveling, breaches were the most commonly observed surface active behavior.

While milling (non-directed swimming) or while drifting (no active swimming), whales frequently were seen rolling, headlifting, and showing their pectorals; less common behaviors included tail lifts, tail slaps and breaches. When several of these behaviors occurred together in a pod of two or more, it was recorded as "frolicking", although no sexual intercourse was observed.

Northbound gray whales exhibited more milling, a wider variety of behaviors, and more occurrences of the behaviors observed. Northbound whales frequently engaged in rolling, headlifts, and pectoral shows. The number of behaviors observed was lower during the southbound migration than during the northbound migration of either non-cow/calves or cow/calves.

Southbound gray whales displayed few social or surface active behaviors, although the types seen (primarily breaching and rolling) are commonly reported along the southbound migration route; no sexual activity was observed. More social and surface active behaviors are reported from areas such as the Channel Islands, where animals appear to congregate and mill before crossing the Southern California Bight.

Interactions between Gray Whales and Vessels

The study area is generally isolated from sport and commercial fishing use; consequently, the number of interactions between whales and vessels was low. During the southbound migration, the speeds of two pods were reduced and the diving behavior and pattern of a third was erratic while they were in the vicinity of a commercial trawler. Another pod made an apparent avoidance maneuver at some distance from a fishing vessel.

Interactions with Other Cetaceans

Juvenile gray whales and cow/calf pairs were seen traveling near the surf zone in company with bottlenose dolphins on three occasions. On another occasion, a cow/calf pair apparently avoided detection by a pod of killer whales by "snorkeling" (i.e. swimming at the surface with only short, shallow dives; exhalation spout seldom visible) near the surf zone.

GRAY WHALE MONITORING STUDY

ABSTRACT

In light of concern that oil and gas development in the OCS may adversely impact the behavior and migration route of the gray whale (*Eschrichtius robustus*), the MMS funded a study of gray whale behavior and migration corridors offshore Point Sal, Santa Barbara County, California. Point Sal was selected as a study site because an offshore production platform (Julius) was scheduled for installation nearby in 1986. The study was scheduled to collect information before and after installation of the platform in order to measure any changes in gray whale behavior or migration patterns.

Shorebased surveys of the northbound migration to ascertain distance offshore and behavior were conducted in April-May 1986, March-April 1987, and March-April 1988; the southbound migration was monitored in January 1987. Aerial surveys determined density, distance from shore, and direction of heading of gray whales and were conducted in January 1987 (southbound migration) and in April-May 1986, March-May 1987, and March 1988 (northbound migration). The northbound migrants were further categorized as either being Phase A, non-cow/calf pairs, or Phase B, cow/calf pairs.

The results of aerial observations indicated that the migratory corridor off Point Sal was at least 33 km wide, but that most (over 73%) whales passed within 24 km of shore, in water depths of less than 200 m. Most non-cow/calf pods were seen during March and cow/calf pairs during April and May. Mean pod size increased with distance offshore during both the southbound and the northbound-Phase A migrations. If installed at the proposed location, 15 km offshore, platform Julius would be 1 to 3 km east (i.e. inshore) of the center of the northbound migratory corridor and about 1 km west (i.e. seaward) of the center of the southbound migratory corridor.

Gray whale migration patterns in the study area appear to be influenced by coastal physiography and bathymetry. Southbound and northbound non-cow/calves migrate further offshore than cow/calf pairs and cross local embayments as if following depth contours. Northbound non-cow/calves traveled about 3 km closer to shore than southbound non-cow/calves, although the seaward limits of the two migration corridors were similar.

At Point Sal southbound non-cow/calves averaged 7.2 km/hr, whereas northbound non-cow/calves averaged 5.1 km/hr. Cow/calf pairs averaged about 5.0 km/hr. Previous studies along the Pacific Coast indicated that southbound gray whales swim at 5 to 10 km/hr with little difference between day and night rates.

Diving/surfacing patterns of gray whales near Point Sal included: 1) one long dive alternating with several short dives; 2) regular long dives; and 3) irregular or unpatterned dives. Southbound non-cow/calves averaged 0.5 min for short dives; 4.0 min for long dives; and 2.5 min for all dives combined. Cow/calf pairs averaged shorter dives in all categories. The duration of dives by single southbound and northbound whales were longer than by pods of two or more. Northbound non-cow/calves averaged 0.5 min for short dives; 4.0 min for long dives; and 2.4 min for all dives.

SECTION I

GRAY WHALE MIGRATION LITERATURE REVIEW

INTRODUCTION

This review is limited to studies of gray whale behavior and migration patterns between Unimak Pass, Alaska, and the United States-Mexico border. Bird (1983) and Miles (1984) conducted gray whale literature reviews which are more extensive spatially and included potential impacts on behavior. In addition, the Coastal Ecology Research Laboratory (1987) compiled a comprehensive bibliography which is cross-referenced by geographic area and subject.

The Eastern Pacific population of gray whales (the "California" gray whale) appears to be the last of what were three distinct populations. The gray whale has undergone numerous nomenclatural changes in the past, but today it is generally accepted that it is properly called *Eschrichtius robustus* (Lilljeborg 1861). It is the same species known from the Western Pacific (the Korean stock), in the Western Atlantic, and from fossils found in Europe (Barnes and McLeod 1984).

The Western Atlantic population is generally believed to have gone extinct several hundred years ago (Mead and Mitchell 1984), but the status of the Korean stock is problematical. The last individual of the Korean stock was thought to have been taken in 1933 (Mizue 1951), however, additional specimens were taken in 1942, 1959, and 1968 (Bowen 1974). Negative results of personal searches for gray whales in 1970 to 1972 led Bowen (1974) to conclude that the last three whales captured were strays from the California stock and that the Korean stock was extinct. However, Brownell and Chun (1977) disputed Bowen's conclusions and reported the capture of at least 67 gray whales between 1948 and 1966, and sightings in 1968 and 1974; they believe the Korean stock still exists, although in dangerously low numbers.

The California gray whale is probably best known for its annual migration. Each year the majority of the population migrates from feeding grounds in arctic seas to mating and calving grounds in coastal lagoons of Baja California and the Gulf of California and back again (Figure 1). The total, round-trip distance of approximately 12,000 km (7,456 miles) is the longest any marine or terrestrial mammal is known to travel on a regular basis.

From November through mid-summer, most gray whales are in transit from the Arctic to Mexico, having left the Bering Sea through Unimak Pass between late October and January (Braham 1984b). Most gray whales spend at least part of January and February of each year in the lagoons and coastal waters of Baja California and the Gulf of California, where calving and mating, but very relatively little feeding, takes place (Norris *et al.* 1983). However, a small fraction of the total population overwinters off British Columbia (Darling 1984), Washington, Oregon, and Northern California (Rice and Wolman 1971). Off Vancouver Island, 35 to 50 gray whales are resident during the summer months (Darling 1984) and individuals have been identified on the basis of photographs of natural markings. Observations of these whales indicate that while 37% were only seen one year, 63% returned for more than one year, a few for as many as eight years.

In northern California, small "summering" pods of 6 to 8 individuals have been observed near St. George Reef (offshore Crescent City), near Patrick's Point, at the mouth of the Klamath River, and adjacent to the Farallon Islands. At St. George Reef the migration pattern was one of whales congregating until larger groups were formed and all animals continued south together (Dohl *et al.* 1981a).

The northbound migration consists of two pulses or phases. Phase A (Poole 1984) occurs primarily in February and March in central California and includes sub-adults, males, and non-mother cows. Phase B passes central California largely in April and May and consists almost entirely of cow/calf pairs (Poole 1984).

Because of these pulses, northbound gray whales are seen from any particular place over a longer period of time than southbound animals. The apparent longer migration time is also a function of the whales' differential arrivals at and departures from Mexico as well as differences in average swimming speeds. Gray whales do not migrate in mass in either direction, however, and therefore in the southern portions of their migratory corridor, some may be going south, while others are in Mexican waters, and still others are heading north.

GRAY WHALE POPULATION STATUS

Scammon (1874) estimated that the Eastern Pacific population of gray whales numbered about 30,000 between 1853 and 1856. However, the discovery of the wintering grounds in Baja California led to heavy whaling between 1860 and 1890 and severe depletion of the population, perhaps to just a few thousand individuals by 1900 (Gilmore 1960).

In 1937 the International Agreement for the Regulation of Whaling afforded the gray whale limited protection from a few nations; in 1946 Japan and the U.S.S.R. joined 15 other nations in signing the International Convention for the Regulation of Whaling, which forbade all killing of gray whales except by contracting governments for scientific research and by certain aborigines for consumption. Since 1951 all nations operating in the North Pacific are subject to provisions which protect the gray whale from commercial exploitation (Reeves 1984). As of 1978, 178 gray whales can be taken each year for use by aborigines, but not for commercial purposes (Reeves 1984).

Estimates of the gray whale population size have been based on two general methods, shorebased counts and aerial surveys, each of which has advantages and disadvantages. Most gray whales migrate within a few kilometers of shore and thus shorebased counts have been used extensively to assess their population size. However, this method has three obvious weaknesses: some whales pass a given spot during the night, when they cannot be seen; some whales pass too far from shore to be seen, even under ideal viewing conditions; and unless the observation post is manned year-round, some whales pass before or after the survey is conducted. Breiwick and Dahlheim (1986) concluded that the present offshore distribution of gray whales needs to be verified by aerial surveys or perhaps from a fixed platform at a distance from shore.

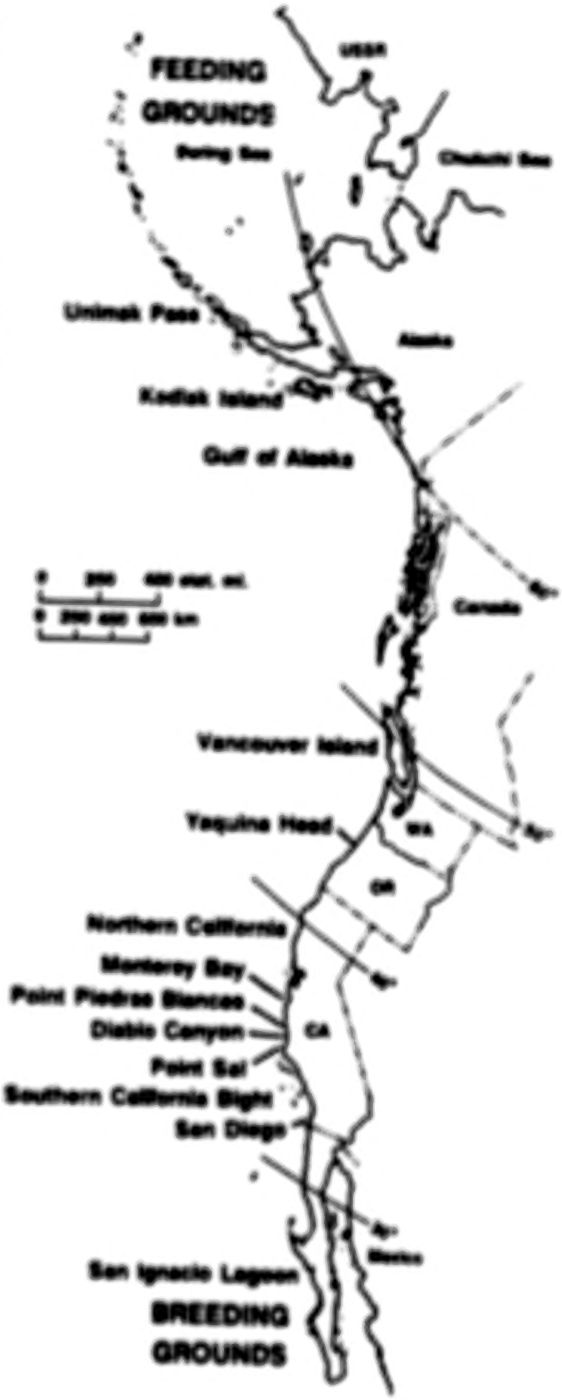


Figure 1. Area map of the gray whale range in the eastern Pacific Ocean with referenced geographic locations.

Reilly (1984) reviewed efforts to establish the size and trends of the gray whale population and lists 42 shorebased censuses which were conducted between 1946 and 1981; one survey was conducted prior to 1946, that in 1865. Thirty-five of the 42 modern surveys were made during the gray whales' southbound migration; the first of 7 censuses of the northbound migration was not conducted until 1977. Possible reasons for this emphasis include the facts that the southern migration is more compact temporally and that cow/calf pairs in the northbound migration were previously thought to travel a distant, offshore route (Poole 1984).

SHOREBASED CENSUSES OF SOUTHBOUND MIGRANTS

Between 1946 and 1960, 11 shorebased surveys were made by Hubbs and others at La Jolla and by Gilmore at La Jolla and Point Loma (Walker 1949, Gilmore 1960, Rice 1961). Five more surveys were conducted at Point Loma between 1967-1968 and 1976-1977 (Rice and Wolman, unpubl., as cited in Reilly 1984). As a result of these surveys it was realized that many whales pass those sites out of view from land (Rice 1965), possibly because the offshore islands in southern California attract whales (Gilmore 1978). There was also evidence that the proportion which migrate offshore might be increasing, perhaps because of increased nearshore boat traffic.

Analysis of data obtained from Point Loma -- in years in which visibility was generally good and the surveys complete -- indicated that the gray whale population increased approximately 11% per year between 1952 and 1957 (Gilmore 1960). Population estimates for the 1952-1953, 1954-1955, and 1956-1957 southbound migrations were 2,894, 3,603, and 4,454 individuals, respectively. Actual shore counts were adjusted upwards for periods of poor visibility as well as for night and offshore passage of whales.

In a continuation of Gilmore's Point Loma surveys, Rice (1961) estimated that the southbound population of gray whales in 1959-1960 was 6,069 individuals, representing an annual increase of over 10%. Rice (1965) suggested that the large proportion of whales which is missed by the counts conducted at Point Loma renders absolute population size estimates erroneous, although they may be a reliable index of relative population size.

In 1967 the National Marine Mammal Laboratory initiated 13 consecutive years of monitoring the southbound gray whale migration from Monterey County, California. The first seven surveys were conducted from Yankee Point and the last six from Granite Canyon. These sites were selected because gray whales were known to pass close to shore and because, compared to Point Loma and La Jolla, there is less boat traffic and human activity and no offshore islands. On the basis of these shore censuses, Reilly *et al.* (1983) estimated that the gray whale population increased from 10,414 in 1971-1972 to 17,577 in 1979-1980 (Figure 2). This represents an annual increase of 2.5% over the study period, a rate which would be 3.75% if the Soviet subsistence fishery did not exist.

On the basis of a partial count of southbound migrants at Yankee Point in Monterey County, Adams (1968) estimated the population of gray whales at 18,300 individuals. Extrapolation of earlier counts by Gilmore (1960) and Rice (1961) would have given an estimate of 12,600 animals in 1966-1967, whereas Hubbs and Hubbs (1967) estimated that the population remained unchanged, at about 3,000, since 1954. As with other analyses, Adams' actual counts were adjusted upwards for night passages, daylight passages when no monitoring was done, and for offshore passage. However, Adams counted whales only about 3 hours per day on days when viewing conditions were good, which might have led to the relatively high estimate.

On the basis of shore counts at both Point Loma and Yankee Point, Rice and Wolman (1971) calculated an upper limit for the gray whale population of 13,000 in 1967-1968. Their estimated upper limit of 12,000 for the 1969-1970 southbound migration was based upon counts made only at Yankee Point.

Using the methods of Reilly *et al.* (1983), Breiwick *et al.* (1985) estimated the gray whale population passing the Granite Canyon site at approximately 18,477 in 1984-1985. Breiwick and Dahlheim (1986) calculated the population to be 14,658 in 1985-1986, an estimate which did not include a correction for whales passing out of sight. Had the same factor been used as in 1984-1985 (1.21) an estimate of 17,751 would have been obtained.

The most recent estimate of the gray whale population was obtained at Granite Canyon (Monterey County, California) by Breiwick *et al.* (1988) during the 1987-1988 southbound migration. Paired sightings by independent observers were used to estimate viewing error and aerial transects were flown to establish

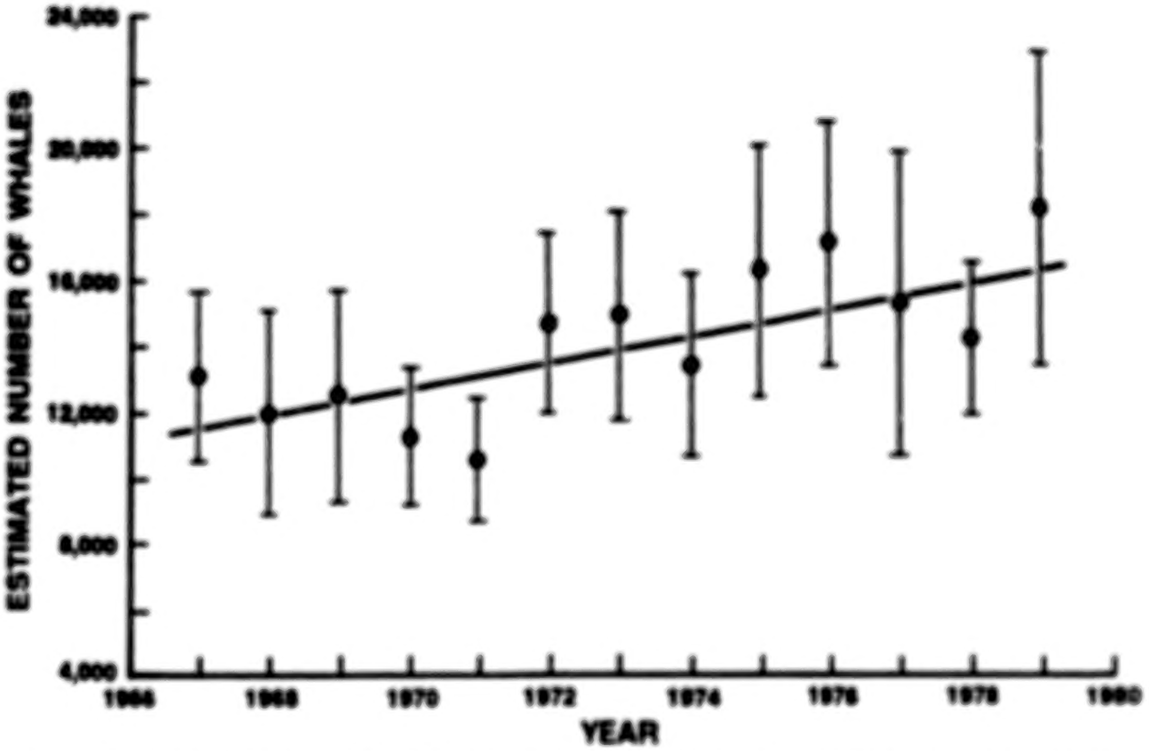


Figure 2. Population estimates of the California stock of gray whales from 1967-68 to 1979-80 with 95% confidence intervals. Fitted line is from exponential regression weighted by variances. (Source: Reilly *et al.* 1983).

the whales' offshore distribution. Their preliminary estimate was 21,113 individuals, with a standard error of 688.

In 1977 Rugh and Braham (1979) conducted a pilot census of the southbound migration at Unimak Pass and Rugh (1984) reported the results of surveys of the southbound migration at Unimak Pass in 1978 and 1979. Using standard extrapolations and selecting 1978 as the primary census year, Rugh estimated the gray whale population at 16,928 individuals. That estimate assumed that whales travel the same speed at night as during the day; if whales slow down, as has been speculated, the estimate may be 17% high.

The southbound migration was monitored at Yaquina Head, Oregon from 1978 to 1980 by Herzing and Mate (1984). Their estimates of the gray whale population in 1980 ranged from 13,627 to 21,854 individuals, depending on the correction factors used.

SHOREBASED CENSUSES OF NORTHBOUND MIGRANTS

Hall *et al.* (1977) conducted a shorebased survey of northbound gray whales at Unimak Pass in 1976. Studies from this northern location are complicated by the fact that the northward migration takes as long as four months, and would require that much time in the field to include the entire migration. Because there is more inclement weather at this site than further south, extrapolations to get accurate estimates are more tenuous.

On the basis of about four months of monitoring, Hessing (1983) estimated that 14,146 gray whales entered the Bering Sea through Unimak Pass in 1981. Their estimate assumed equal day and night traveling rates but was not corrected for whales which may have passed before or after the period of study.

Poole (1984) censused the northward migration from a shore station at Point Piedras Blancas in central California in 1980 and 1981. His estimates of the gray whale population size (15,725 in 1980 and 16,140 in 1981) were corrected for whales passing at night and too far offshore to be seen, as well as for observer error in estimating pod sizes.

AERIAL CENSUSES IN THE WINTER RANGE

Reilly (1984) lists 21 aerial censuses of the gray whale since 1952 in their Mexican calving and mating grounds. Like shorebased surveys, aerial survey methods have shortcomings which require that actual whale counts be adjusted. These include: the vastness of their range (a synoptic survey of all lagoons and the offshore would be extremely costly and logistically difficult); the timing of the survey, i.e. what portion of the population has not yet entered the study area and what portion has already left; the fraction of animals which are underwater at the time the aircraft passes overhead; weather conditions which affect the visibility of the observers; and the accuracy and precision of the observations, as affected by observer experience and fatigue (Reilly 1984, Hubbs and Hubbs 1967, Gilmore 1960).

Estimates of gray whale population size based on aerial surveys are generally about one-half those based on shore counts (Reilly 1984). In the early 1970s the total population was estimated from aerial surveys at approximately 7,000 individuals (Gard 1974) and in 1981 at about 7,600 (Rice *et al.* 1983). In shorebased surveys, by contrast, Herzing and Mate (1984) estimated that the southbound migration included 15,462 individuals in the 1980-1981 season while Poole (1984) calculated that northbound populations sizes were 15,725 and 16,140 in 1980 and 1981, respectively. Rugh (1984) estimated the population at almost 17,000 in 1978.

Reilly (1984) suggests that the estimates from aerial surveys of the winter range are probably low, but that shorebased counts might be high. Making a variety of adjustments and corrections, he estimated that the total population size in 1980 was between 14,300, if whales move more slowly at night than in daytime, and 15,600, if they travel at the same rate, day and night.

Although estimates of the absolute size differ and are subject to debate, there is little doubt that the gray whale population has grown considerably since it was afforded protection. Estimates of the population size in the 1950s suggest an annual increase of 10 to 11% (Gilmore 1960). Reilly *et al.* (1983) analyzed 13 years of data obtained near Monterey, California and found a increase of about 2.5% per year between 1967 and 1979.

THE SOUTHBOUND MIGRATION

The impetus for the onset of the southward migration is not firmly established, although Pike (1962) indicated that the advance of ice through the Bering Strait initiates migration for most gray whales. Rice and Wolman (1971) collected 180 southbound individuals (85 males and 95 females) between Half Moon Bay and Point Reyes, California for scientific study. On the basis of gonadal analyses, they established the following order of migration: 1) late pregnant females; 2) recently ovulated females; 3) adult males; 4) immature females; and 4) immature males. The earliest southbound migrants usually travel singly, whereas later migrants normally travel in pods of 2 or more (Rice and Wolman 1971). Presumably this also represents the order in which they embark on the southern migration through Unimak Pass. The approximate timing of southbound gray whales' passage past key landmarks is indicated in Figure 3.

Unimak Pass, Alaska

In 1977, southbound whales were observed moving through Unimak Pass from late October through December, with peak concentrations between November 20 and December 9 (Rugh and Braham 1979). About 30% of the whales observed from the shore station at Cape Sarichef were more than 815 m from shore, and 70% were within 815 m of shore. Seventy-three percent of those passing within 50 m of shore were small or yearlings, whereas 77% of those further than 100 m from shore were medium or large whales.

SOUTHBOUND TIMING

SOURCE	PEAK PASSAGE	RANGE PASSAGE
Rugh and Braham 1979		late October - December
Darling 1977	December 15 - 30	November thru late January
Herzing and Mate 1984	late December - early January	early December - early February
Dohl *et al.* 1983	late December	mid November
Behrens *et al.* 1985		mid November - late January
Dohl *et al.* 1981b Leatherwood 1974	January	mid December - February
Rice and Wolman 1971	January	early January - early February

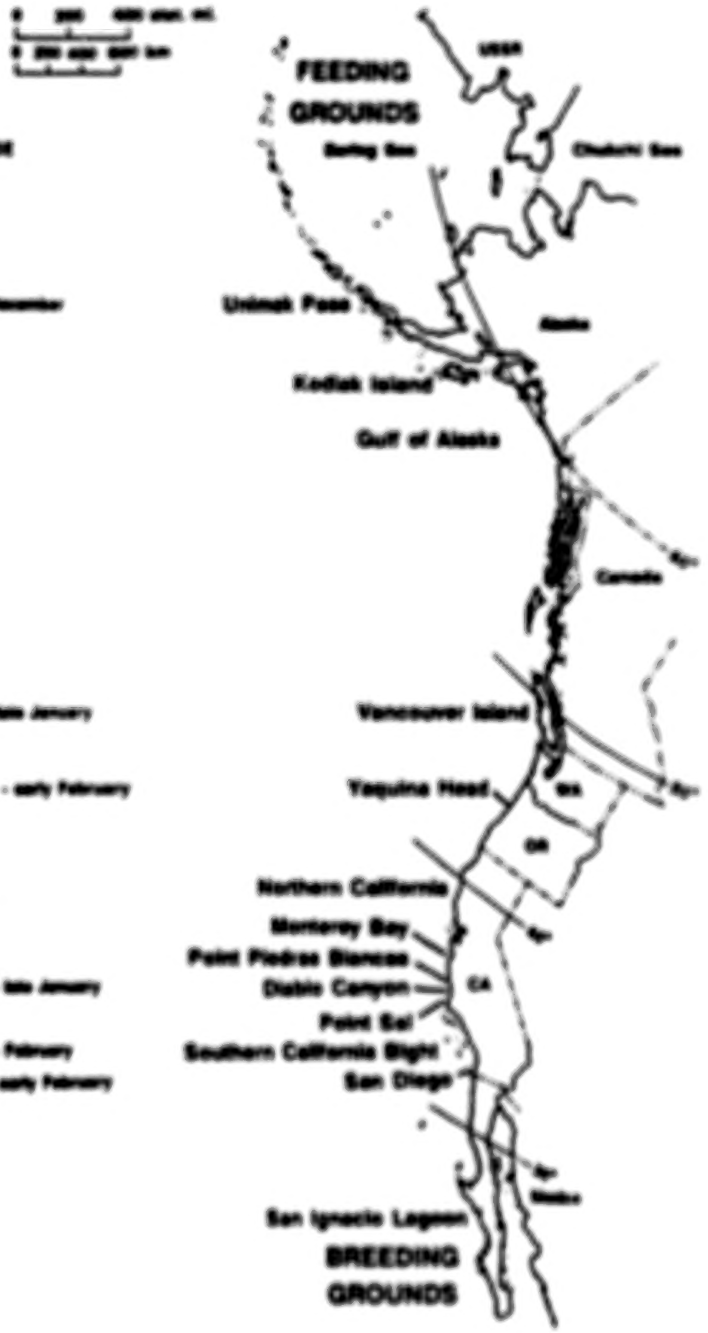


Figure 3. Timing of the southbound gray whale migration past key landmarks.

Shorebased and aerial observations at Unimak Pass in 1980 (Rugh 1981) indicated that gray whales follow the eastern edge of the Pass, and that 92% are within 1.4 km of shore. The distance offshore was to some extent a function of sea state (Rugh 1984), whales traveling closer to shore in calm conditions and further offshore during periods of high surf. The average size of whales going through the Pass decreased with time. Adults were more common early in the migration and juveniles toward the end, an observation which is in agreement with Rice and Wolman (1971) findings for the order of migration.

Gulf of Alaska

Scammon (1874) speculated that gray whales follow a coastal route along the southern coast of the Alaskan Peninsula and the Gulf of Alaska and this was generally accepted until Gilmore (1955 and 1960) suggested that they cross open water from the Bering Sea to British Colombia. Pike (1962) analyzed data from several previous workers and hypothesized that the southern (and probably the northern) migration was close to shore throughout Alaskan waters, just as it is between Canada and Mexico.

A series of air-, ship-, and landbased surveys (Consiglieri and Braham 1982, Rugh and Braham 1979, Braham 1977, Braham *et al.* 1977) between 1975 and 1981 tend to confirm that southbound gray whales leave the Bering Sea via Unimak Pass and follow a coastal route throughout the Gulf of Alaska (Braham 1984a). Rugh (1984) reported that the southbound migration was largely within 3.7 km of the south coast of Unimak Island. Brueggeman *et al.* (1987) observed that southbound gray whales "island hopped" between Unimak Pass and Kodiak Island and speculated that this maximized their travel in shallow water.

Vancouver Island, British Columbia

Off British Columbia the southbound migration is almost entirely to the west of Vancouver Island (Hatler and Darling 1974, Pike and MacAskie 1969, Pike 1962). During four winters between 1972 and 1977 relatively few southbound migrants were observed, although this may have been because of poor weather and visibility. Southbound whales have been seen from light stations between November and late January, with peak numbers during the last two weeks of December (Darling 1977).

During southbound (and northbound) migrations over 50% of all whales observed off Vancouver Island were between 1.6 and 3.2 km of shore (Darling 1984). As the direction of the migration changed from southward to northward, there was a trend of decreasing distance from shore, indicating that northbound whales migrate closer to shore.

Yaquina Head, Oregon

Herzing and Mate (1984) monitored the southbound migration past Yaquina Head, Oregon during three seasons from 1978 to 1981. The first southbound migrants were seen between 2 and 11 December and the last between 1 and 9 February. Peak abundances were recorded on 28 December, 1978 (22 whales/hr), on 6 January 1980 (29 whales/hr) and 1 January 1981 (29 whales/hr). During 1979-1980 and 1980-1981, the southbound migrants were equally divided between those in pods of 1 or 2 individuals and those of 3 or more (Herzing and Mate 1984).

In 1979-1980, 20% of all gray whales sighted from shore were within 1.6 km of shore at Yaquina Head; 60% were between 1.6 and 3.2 km of shore and the remaining 20% were from 3.2 to 4.8 km offshore (Herzing and Mate 1984). In 1980-1981, the migration shifted offshore somewhat: 10% of the whales were within 1.6 km of shore, 55% were between 1.6 and 3.2 km, and 35% from 3.2 to 4.8 km offshore.

In 1981 aerial observations were made over a period of three days to distances of 32 km from Yaquina Head (Herzing and Mate 1984). These revealed that 39% of the passing gray whales were more than 4.8 km from shore, the limit for shorebased observations. During the southbound migration in 1980-1981, 36% of all whales seen from shore were between 3.2 and 4.8 km from shore. However, during the period of the aerial surveys, shorebased observations indicated 46% of the whales observed were in the 3.2 to 4.8 km region and aerial survey data restricted to 4.8 km revealed 68% of the whales in the same region. Thus, there was evidence (Herzing and Mate 1984) that shorebased observations miss many offshore whales, and indicate that on average they travel closer to shore than they actually do.

Monterey, California

On the basis of 13 years of consecutive censuses near Monterey, Reilly *et al.* (1983) determined that the seasonal timing of the southbound migration was relatively constant. The overall mean day by which half the population had passed was 9 January, with yearly means ranging from 8 to 19 January. Surveys were conducted for 10 hrs per day, 7 days per week, usually from about 10 December to about 6 February, the extremes of the gray whales' local migration.

There has apparently been a offshore shift of the gray whale migratory corridor since the late 1970s. In 1978-1979 and 1979-1980 the mean distances of pods from shore (as observed in aerial surveys) were 0.75 and 0.64 miles, respectively (Table 1; Reilly *et al.* 1983). Shorebased observations of the 1984-1985 and 1985-1986 migrations indicated mean distances from shore of 1.11 and 1.33 miles, respectively (Breiwick and Dahlheim 1986).

There was also a statistically significant tendency for pod sizes to increase with distance offshore during the southern migration (Figure 4, Reilly *et al.* 1983). The apparent increase in pod size with distance offshore may be real or it could be an artifact, because observers miss small pods at greater distances or because several small pods are judged to be a single large pod due to the compression of the viewing angle at greater distances. A similar tendency toward migration further offshore was observed in aerial surveys in southern California (Dohl and Guess 1981). However, there does not seem to be similar evidence from aerial surveys between Point Arguello and Half Moon Bay, California (Dohl *et al.* 1981a) or from land at Monterey (Reilly *et al.* 1983).

Table 1. Numbers of whales observed within each of seven distance intervals from shore in aerial transects during 1978-79 and 1979-80 with an X^2 = <5.025 <X^2 <6.025.

Interval	Distance (m)	Number Observed 1978-1979	1979-1980	% Pooled
1	0-0.25	14	11	2.91
2	0.26-0.5	36	33	8.02
3	0.6-0.75	41	42	9.65
4	0.76-1.0	74	88	18.84
5	1.1-1.5	148	167	36.63
6	1.6-2.0	74	61	15.70
7	2.1+	29	42	8.26
Total		416	444	

Source: Reilly et al., 1983

In 1968 offshore cruises were made up to 37 km from shore at Yankee Point. No gray whales were seen further than 6.0 km from shore; 9 of 33 observations (27%) were from 4.5 to 6.0 km from shore and the other 24 (73%) were within 1.5 km of land (Rice and Wolman 1971).

In 1973 aerial surveys of gray whales were undertaken simultaneously with shore surveys south of Monterey Bay (Sund and O'Connor 1974). Although the aerial survey extended 40.2 km to sea, all of the 50 observations (149 animals) were within 11.3 km of shore: 98% were within 8.1 km of shore and 94% were within 1.6 km. These results confirm an earlier estimate based on shore observations (Rice and Wolman 1971) that 95% of the whales pass within 1.9 km of the Yankee Point observation site. Aerial observations, though useful in quantifying the number of whales in groups, were found to be limited by sea conditions (Sund and O'Connor 1974).

Central California

In December and January 1977 four longshore, aerial surveys were conducted between Monterey and Point Arguello during the southbound migration. The flight path was 1.9 km offshore and observers manned both sides of the aircraft. Approximately 97% of the 442 gray whale observations made were within 2.8 km of shore and no whales were seen further than 4.6 km from shore (Dohl *et al.* 1983). From Point Arguello north to Half Moon Bay, the flight path was 9.3 km offshore and no gray whales were observed, although two animals were seen when the aircraft approached land at the end of the flight.

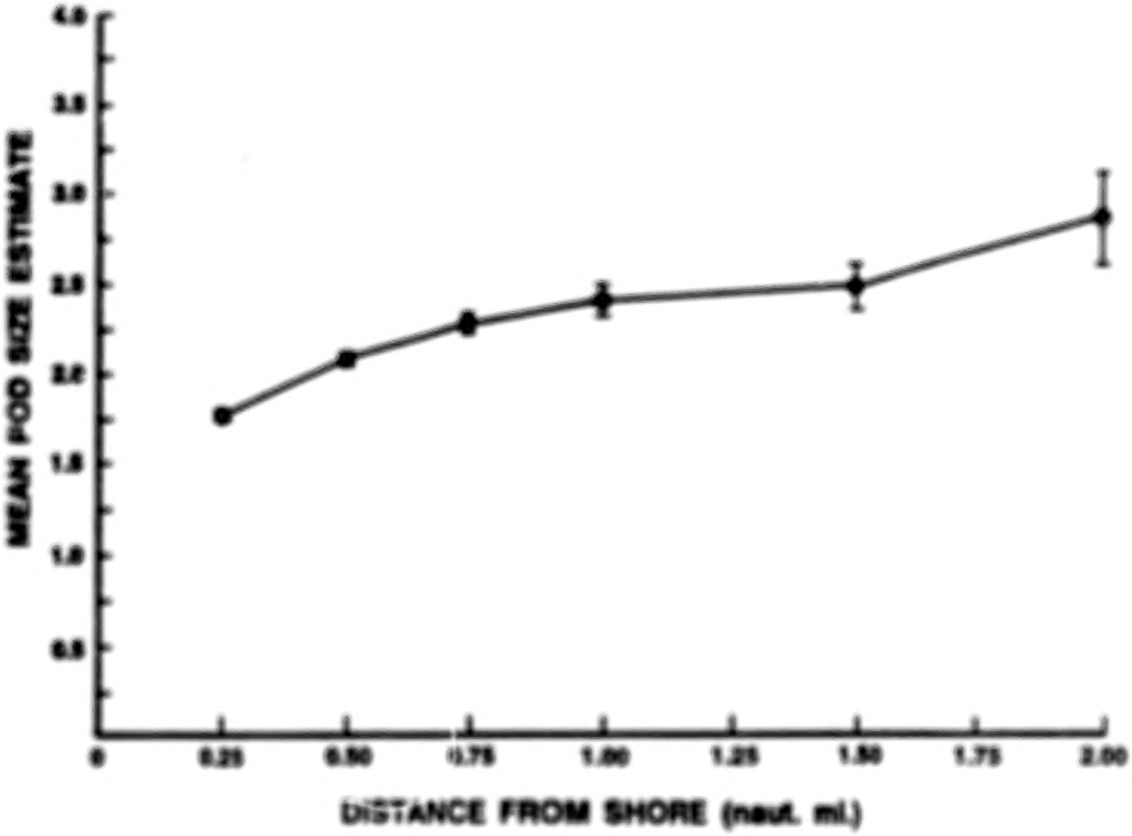


Figure 4. Mean pod size estimates (with 95% confidence limits) by distance from shore near Monterey, California. From 13 annual gray whale censuses, 1967-68 through 1979-80; N=23,678 observations (Source: Reilly *et al.* 1983).

During three years of aerial surveys off northern and central California, southbound gray whales were seen (between latitudes 38° 30'N and 34° 10'N) as early as mid-November, although most passed through in late December (Dohl *et al.* 1983). Only 6.5% of the whales were more than 9.3 km from shore, except in areas such as the Gulf of the Farallones, Monterey Bay, and San Luis Obispo Bay, where they move across open water from headland to headland. Southbound individuals were observed as much as 85 km offshore Mendocino, California (Dohl *et al.* 1983).

Diablo Canyon, San Luis Obispo County, California

The southbound gray whale migration has been monitored from shore at Pacific Gas and Electric's Diablo Canyon Power Plant since 1981 (Behrens 1987, Behrens *et al.* 1985, Behrens and Shaffer 1985, Behrens *et al.* 1984, Behrens 1983). Between 1981 and 1985 the first southbound whale was sighted as early as 18 November and as late as 11 January, while the last was seen as early as 3 January and as late as 22 January.

The distances of whales from shore were tallied among six zones each of which were 305 m wide and parallel to shore (Behrens *et al.* 1985). During the 1983-1984 southbound migration, 49% of the whales seen were between 1.5 and 1.8 km from shore, 34% were between 0.9 and 1.5 km from shore, and 18% were within 0.9 km of the coast (Behrens and Shaffer 1985). Comparable values for the 1984-1985 southbound migration were: 44% from 1.5 to 1.8 km offshore; 39% between 0.9 and 1.5 km from shore; and 18% within 0.9 km of the coast (Behrens *et al.* 1985).

During the 1983-1984 southbound migration pod-size averaged 1.4 individuals and showed distinct patterns with distance from shore. The only whales seen within 0.6 km of shore were single individuals; between 0.6 and 1.2 km, pods of 1 to 3 were observed; and at distances of 1.2 to 1.8 km from shore pods of 1 to 4 individuals were seen.

Southern California Bight

The majority of southbound gray whales travel within a few kilometers of shore in northern and central California, especially where the Continental Shelf is narrow and there are no offshore islands. However, many tend to take the most direct route when crossing bights and indentations of the coastline (Rice and Wolman 1971). At Point Conception, the California coast turns sharply to the east and a sizeable portion of the population follows more offshore corridors toward Mexico. Jones and Swartz (1987) indicate that there are three identifiable routes: the nearshore, mainland corridor, east of the Channel Islands; the inter-island corridor; and the offshore corridor, west of the islands.

The estimated percentage of whales which use offshore routes has increased over the years. Gilmore (1960) estimated that about 5% traveled offshore, but Rice (1965) thought the percentage was higher. During a January 1964 cruise in the Southern California Bight, 15 pods of southbound gray whales were sighted and their distribution indicated that many leave the mainland shore after passing Point Conception and fan out through the Channel Islands (Rice 1965). This pattern was attributed to: 1) unusual oceanographic conditions in 1963-1964; 2) the increasing gray whale population which forced a large proportion of the animals to go offshore; or, 3) the increasingly heavy small boat traffic in inshore waters (Rice 1965). Rice and Wolman (1971) concluded that over half of the migrants pass San Diego's Point Loma too far to be seen from shore.

Kent *et al.* (1980, as cited in Jones and Swartz 1987) estimated that 67 to 80% of the southbound migrants leave the coast at Point Conception and follow an offshore route and Leatherwood *et al.* (1986) estimated that 65 to 75% left the coast and traveled offshore. Stewart and Leatherwood (1986) indicate that over 65% of southbound gray whales continue south at Point Conception and take one of several inter-island routes through the Southern California Bight. They also indicate that there has been an increase in the number of records of southbound whales west of San Nicolas and San Miguel Islands.

Aerial surveys of cetaceans were made monthly from Point Arguello to the United States-Mexico border between 1975 and 1978 (Dohl *et al.* 1981a). Flights were made along 15 transects perpendicular to shore for a total (including connecting cross-legs) of 2,241 km. During the course of the surveys 747 gray whales were sighted. They began to arrive in the Southern California Bight in mid-December and 90% (669 individuals) were seen from January through March. Although gray whales were seen Bight-wide, they were more common near the mainland. The few sightings which were made from April through July were considered unseasonal, but because they were well offshore were interpreted as a shift in migratory pathways (Dohl *et al.* 1981b).

Earlier convention held that the southbound migration is closer to shore than the northbound, but Dohl *et al.* (1981a) found just the opposite in the Bight. Very few southbound animals were seen close to shore between Gaviota and Ventura or between Newport Beach and Oceanside, however, northbound individuals were nearshore and abundant in both of those areas. The study area was divided into 997 sectors 9.3 by 9.3 km; the 73 which abut the mainland constitute the "traditional" gray whale migratory corridor. Dohl *et al.* (1981b) reported that while "traditionally" this corridor should account for 90% of gray whale movement, it accounted for only 38% of their sightings. If the data are adjusted for level of effort (coastal sectors were flown more frequently than those offshore), only 24% of the sightings were in the nearshore corridor.

San Diego, California

In early 1968 seven transects offshore San Diego were surveyed from surface vessels in order to establish the proportion of gray whales which were beyond the view of observers at Point Loma (Rice and Wolman 1971). In 100 km of cruising within 9.3 km of shore (the maximum distance at which whales can be seen from Point Loma), 37 gray whales were seen, an average of 0.37 whales per km. At distances beyond 9.3 km, an average of 0.27 whales per km was observed. It was calculated that 41% of gray whales pass Point Loma within 9.4 km of land where they are potentially visible to shorebased observers.

Periodic aerial surveys of southbound migrations were conducted throughout the Southern California Bight between 1969 and 1972. Peak densities off southern California were in January and over half the population passed San Diego more than 64 km from shore (Leatherwood 1974).

THE NORTHBOUND MIGRATION

The factors responsible for the initiation of the northbound migration of gray whales are not known and neither the beginning nor end of the northward migration is as well defined as those of the southward leg (Dohl *et al.* 1981b). From 1959 to 1970 Rice and Wolman (1971) collected 136 northbound whales (81 males and 55 females) between Half Moon Bay and Point Reyes, California. On the basis of gonadal analyses they established the following sequence of migrants by category: 1) early pregnant females; 2) adult males; 3) metestrous and anestrous females; 4) immature females; 5) immature males; and 6) postpartum females. Presumably this is the same order in which they leave the lagoons of Baja California for the north. The timing of northbound gray whales' passage past key landmarks is indicated in Figure 5.

Hubbs (1959) observed that cow/calf pairs seemed to take a more offshore path and Rice and Wolman (1971) stated that although the (northward) route taken by females with calves was unknown, it was thought to be offshore. However, knowledge of and hypotheses concerning the path of northbound cow/calf pairs have changed considerably in recent years. Baldridge (1974) noted that cow/calf pairs passed very close to shore in the vicinity of Monterey, often moving through the outer fringes of kelp beds. Leatherwood (1974) noted that between 1969 and 1972, cow/calf pairs in the Southern California Bight tended to be inshore, traveling either alone or in the company of other cow/calf pairs. Yearlings (6 to 9 m long) also traveled inshore but were usually alone or with other yearlings.

Recent work (Herzing and Mate 1984, Poole 1984) indicates that the northward migration comprises two pulses, although these are not always distinct and may vary regionally. Phase A (*sensu* Poole 1984) consists of individuals belonging to the first five of Rice and Wolman's (1971) categories above, while Phase B consists almost entirely of cow/calf pairs. Two pulses were also noted going north through Unimak pass in 1981: all sizes of whales were seen throughout the survey, but cow/calf pairs were only seen in the latter part of the study period (Hessing 1983).

Braham (1984b) did not see the same pattern in data he collected between 1975 and 1979 in Alaskan waters, although he does state (p. 263) that "the northbound migration occurs from March through June and is roughly divided into two phases. The first phase apparently includes nonparturient adults and immatures, followed in about one month mainly by cows and young-of-the-year calves."

San Diego, California

Gilmore (1960) reported that the northbound migration first passed San Diego in mid-February, peaked in March and April, and tapered off by early May. He also noted that gray whales veered offshore at Point Loma, passing La Jolla several miles to sea on a course across the Southern California Bight.

Peak numbers of northbound gray whales passed San Diego's Point Loma in the second and fourth weeks of March between 1969 and 1972 (Leatherwood 1974). Twenty-three groups of whales containing cow/calf pairs were observed during aerial surveys, the earliest on 18 February and the latest on 18 May. In 18 of these cases cow/calf pairs were by themselves or with other cow/calf pairs; in only 4 cases did other adults accompany cow/calf pairs. While most of the cow/calf pairs were "well inshore," those late in the migration were observed futher offshore. Leatherwood (1974) noted that a high percentage of northbound whales pass offshore and out of sight of Point Loma, presumably heading between the Channel Islands until they reach Point Conception.

NORTHBOUND TIMING

SOURCE	PEAK PASSAGE	RANGE PASSAGE
Hessing 1983		March-June
Wilke & Fiscus 1961		May
Hall *et al.* 1977		
Pike 1962	mid April	?- mid May
Darling 1984	late March	mid February-April
Hart 1977	early April	
Herzing & Mate 1984	Phase B: mid-May Phase A: mid March	late April-early June late February-late April
Poole 1984	Phase B: mid April Phase A: early March	late March-mid May February-early May
Behrens *et al.* 1983	mid February-early March	late January-early June
Gilmore 1960	March & April	mid February-May
Leatherwood 1974	mid-late March	mid February-mid May

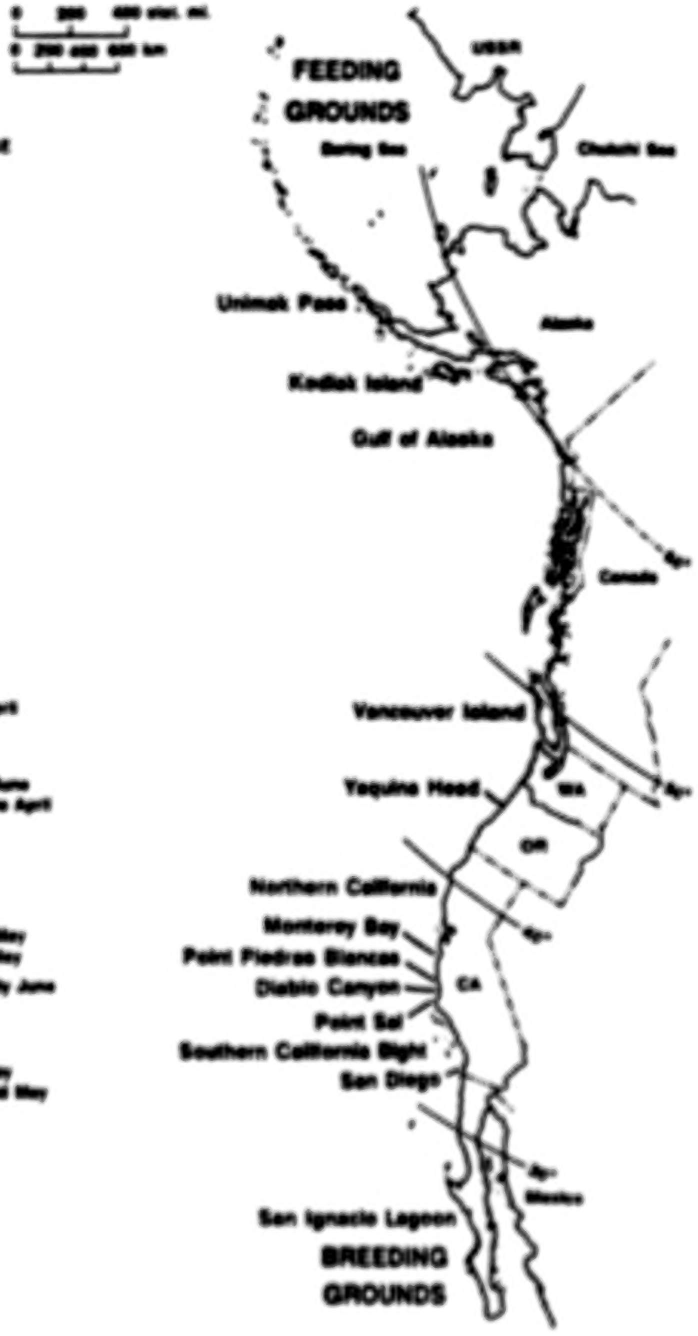


Figure 5. Timing of the northbound gray whale migration past key landmarks.

Southern California Bight

In three years of monthly aerial surveys in the Southern California Bight, over 90% of all gray whale sightings were made from January through March, some moving south and some already moving north (Dohl *et al.* 1981b). Most were relatively close to the mainland coast although whales were observed throughout the Bight. There were also indications that whales traveled progressively further offshore in successive years. Of 47 immature gray whales seen, 17 were within 9.3 km of the coast.

Point Sal, Santa Barbara County, California

Monitoring of gray whale migration patterns by shorebased and aerial observers was recently conducted at Point Sal, California. Preliminary analyses indicate a nearshore migratory path for the northbound, Phase B migrants. In 6 days (80 hrs) of observation between 30 April and 6 May 1986, 55 cow/calf pods, comprising 138 individuals, were seen. Seventy-one percent of the pods were single cow/calf pairs and 20% were double pairs. One pod comprised 1 cow and 2 calves; although not previously reported in the literature, Poole (pers. comm.) observed a similar pod at Point Piedras Blancas in 1981.

All but one pod seen from shore at Point Sal were within 2 km of shore. Thirty-nine percent of the pods were within 0.25 km of the shore, 43% between 0.25 and 0.5 km of shore, and the other 18% were further offshore (MBC 1987). While within view of observers at Point Sal, cow/calf pods spent 15% of their time milling and 85% of their time traveling.

Just south of Point Sal northbound cow/calf pods followed one of three basic paths. From Milling Area 1, 5 km southeast of the Point (Figure 6), most pods followed a Primary Route close to shore, usually within 200 m. Some pods cut approximately half-way across the open embayment southeast of the Point, following a Secondary Route from Milling Area 2 north of Reef to Lion Rock. A few pods took a more direct Tertiary Route across the open mouth of the embayment. Malme *et al.* (1983) also observed cow/calves milling and Poole (1984) saw similar milling and movement patterns at Point Piedras Blancas.

Diablo Canyon, California

The northbound migration of gray whales has been monitored from shore at the Diablo Canyon Power Plant since 1981-1982 (Behrens 1983, Behrens *et al.* 1984, Behrens and Shaffer 1985, Behrens *et al.* 1985, Behrens 1987). In the four years from 1981 to 1985, the first northbound gray whales were seen between 24 January and 15 February, while the last were seen between 27 April and 3 June. In the 1984 migration, peaks of abundance were noted about 10 February and 5 March; in 1985 there was a strong peak in early March, and a more diffuse one the last week of March through the first week of April. In 1984 (Behrens *et al.* 1985) these peaks corresponded to Phases A and B of Poole (1984); however, in the 1985 migration the similarity was not apparent (Behrens and Shaffer 1985).

At the Diablo Canyon research site, the distance of each pod from shore is recorded in one of six zones 305 m wide which parallel the coast. In 1984, 59% of the northbound migrants were between 1.8 and 1.2 km from shore; 26% were from 1.2 to 0.6 km from shore; and 15% were within 0.6 km of the coast. Corresponding percentages in 1985 were approximately 40%, 38% and 23%.

Point Piedras Blancas, California

Poole (1984) monitored the northward migration of gray whales in 1980 and 1981 from shore at Point Piedras Blancas, California. Using theodolite methods similar to those of Reilly *et al.* (1980) he established distances from shore as well as numbers. Shore observations were supplemented with aerial observation in 1981.

In 1980 observations began on 10 March, when Phase A was apparently underway (Poole 1984). The numbers gradually tapered off until mid-May when no additional whales were observed. The first cow/calf pair was seen the week of 22 to 29 March, and peak numbers passed Point Piedras Blancas between 19 and 26 April (Figure 7). Northbound whales were from 10 m to 3.2 km from shore, and the mean weekly

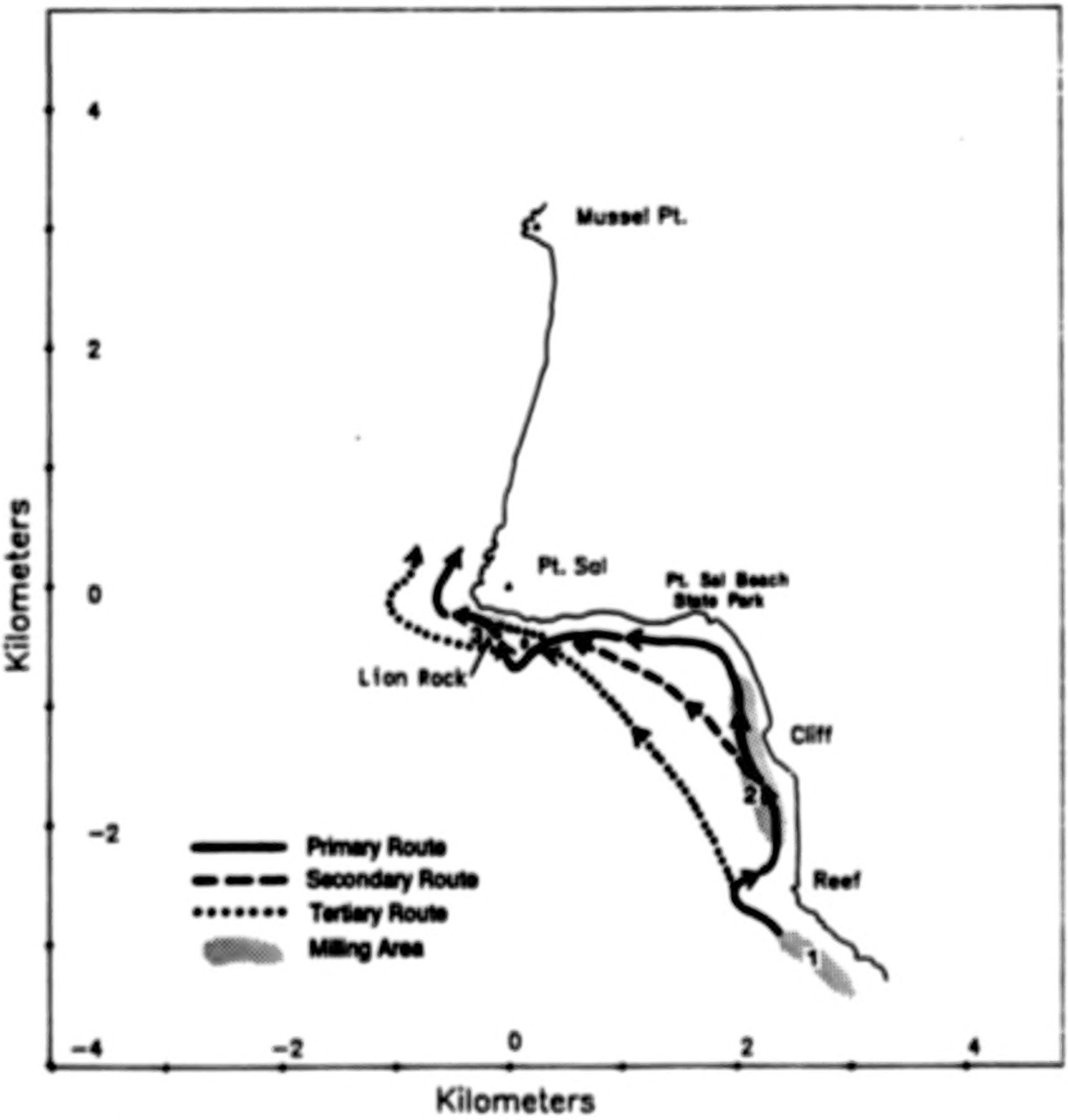


Figure 6. Migratory corridors of northbound cow/calf pairs in the vicinity of Point Sal, California, May 1986.

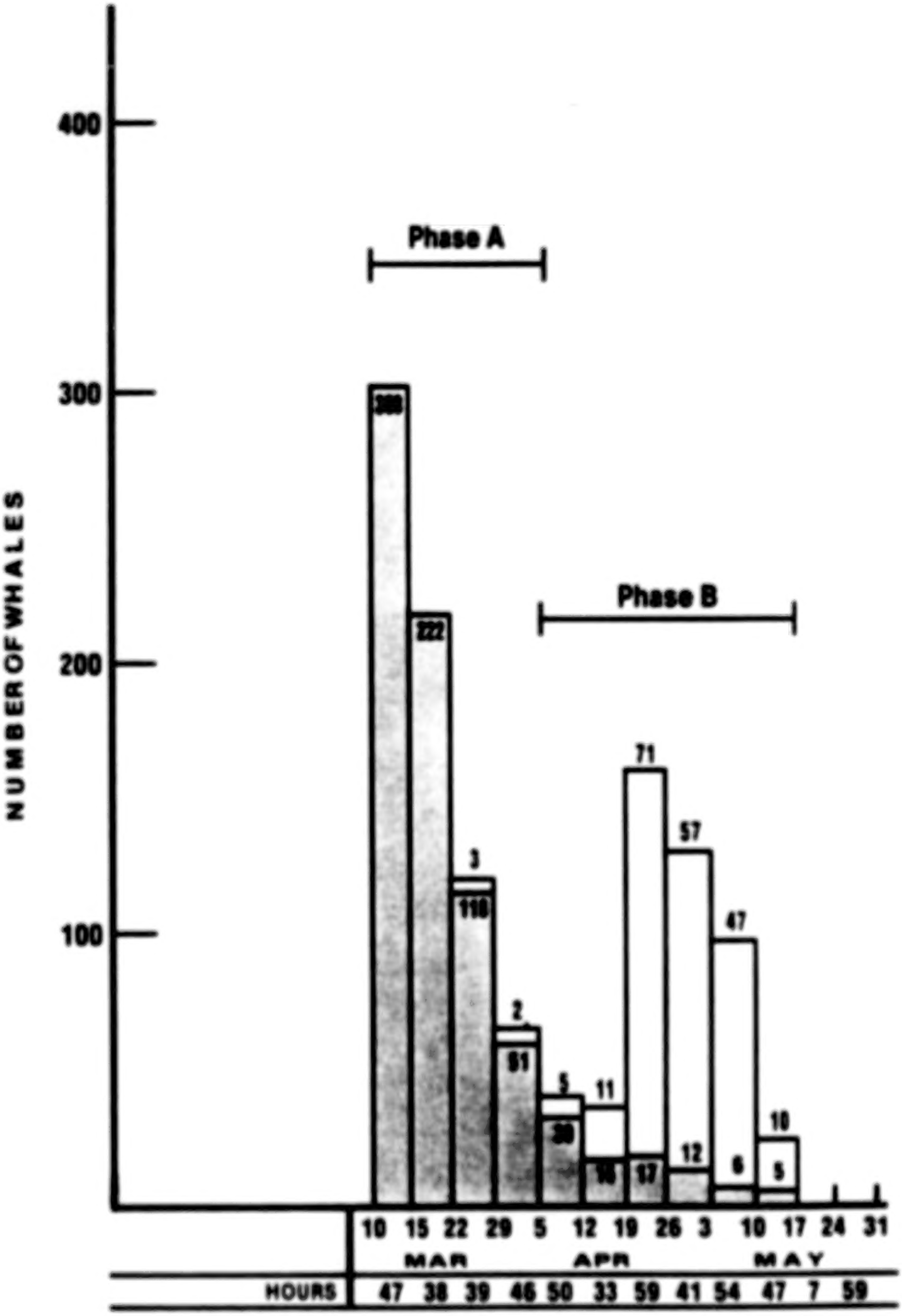


Figure 7. Weekly counts of northbound, Phase A and Phase B gray whales past Piedras Blancas in 1980. Solid bar = individuals; open bar = cow/calf pairs. (Source: Poole 1984).

distance from shore diminished over the course of the entire study. During Phase A, the weekly mean distance from shore declined from 1.4 to about 0.5 km, while the cow/calf pairs in Phase B averaged about 150 m from shore (Figure 8).

In 1981 the Phase A migration was underway when observations began on 9 February and it peaked during the first week of March (Poole 1984). The first cow/calf pair appeared during the first week of April, indicating the beginning of Phase B. The weekly abundance increased through the first week of May (Figure 9). The mean distance from shore during Phase A declined steadily from 2.2 km, when observations began, to about 0.5 km at the end of the pulse. The pods of Phase B averaged about 200 m from shore, and showed some evidence of being closer to shore when most abundant (Figure 10).

The northward migration was clearly bimodal in both years; the first pulse (Phase A) was composed almost exclusively of "singles" (i.e. other than cow/calf pairs) and the second (Phase B) of cow/calf pairs. Poole (1984) concluded that the non-cow/calf singles follow an offshore corridor from headland to headland, avoiding bights in the coastline. Sixty-seven percent were from 0.8 to 3.2 km offshore Point Piedras Blancas; 20% were between 200 m and 0.8 km offshore; and 13% were within 200 m of shore. Phase B gray whales (90% of which were cows and calves) followed approximately 6 weeks behind those of Phase A and much closer to shore. In 1980 and 1981, 99 and 96% of these animals, respectively, were within 200 m of Point Piedras Blancas. Aerial observations in 1981 and 1982 confirmed that these patterns were valid along a 96-km stretch of coastline in the vicinity of the shorebased study area.

Poole (1984) postulated two possible advantages for cow/calf pairs using a nearshore migratory corridor: 1) the more readily available food in shallow water, and 2) the protection from predators offered by kelp beds, both physically and by presenting an acoustic screen from killer whales (S. L. Swartz, pers. comm. to M. Poole 1984). Poole (pers. comm.) observed apparent feeding at Piedras Blancas and there is ample evidence that northbound gray whales feed on a variety of organisms, including mysid shrimp in kelp beds, throughout their migration corridor (Nerini 1984).

Poole (1984) suggested that earlier studies did not observe the nearshore movement of cow/calf pairs because observations were terminated after the Phase A animals passed (i.e. before cow/calves arrived) and/or because there were relatively few cow/calf pairs in the previously depleted population.

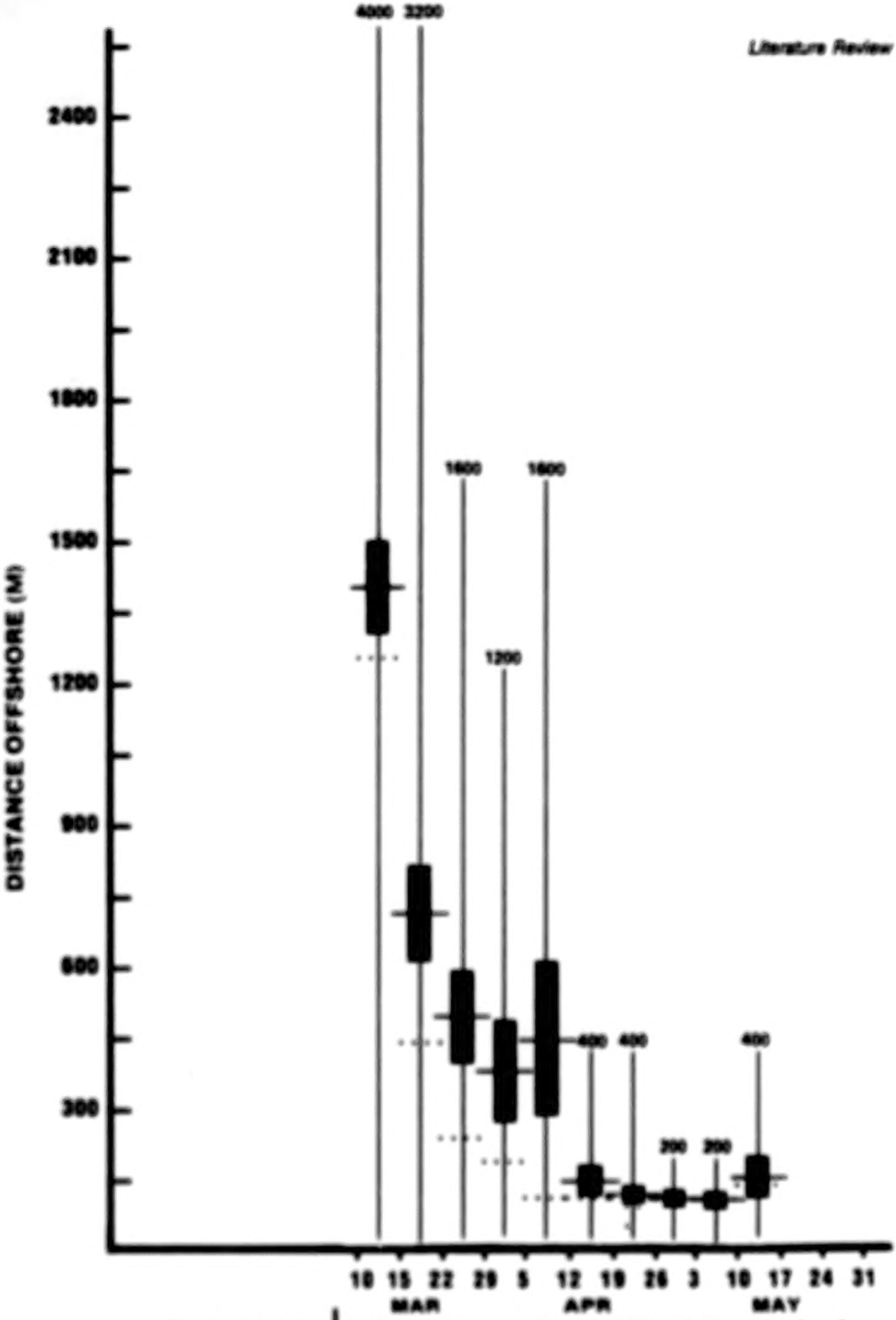
Northern and Central California

A two-phase northbound migration pattern has also been observed from aerial surveys in central and northern California. Northbound cow/calf pairs (Phase B) off the Monterey Peninsula traveled closer to shore than southbound animals in 1983 (Maime *et al.* 1983). Northbound gray whales were generally closer to shore than southbound animals and only about 2% of the northbound animals observed were more than 9.3 km from shore, except in the Gulf of the Farallones where open-water traverses are common (Dohl and Guess 1981, Dohl *et al.* 1983). The Phase A animals traveled from headland to headland, whereas the cow/calf pairs were very close to shore, often in kelp beds or just offshore the surf zone. There did not seem to be the same trend for gray whales to travel further offshore in successive years along the northern and central California coast as was observed in the Southern California Bight (Dohl *et al.* 1981b).

Yaquina Head, Oregon

Observations of the northbound migration at Yaquina Head, Oregon in 1980 and 1981 revealed the same bimodal pattern described by Poole (1984) off central California (Herzing and Mate 1984). In the 1980 survey, Phase A began in late February and was over by the end of April, with peak abundances of singles passing in mid-March. Phase B began in late April, peaked in mid-May and ended in early June (Figure 11).

In 1981 Phase A of the northward migration began off Yaquina Head in mid-February, peaked in mid-March, and was over by the end of April (Figure 12). Phase B began in late April and was essentially over by the end of May, having peaked about 10 May (Herzing and Mate 1984).



Number of Whales	300	222	124	55	48	38	159	125	100	25	0	0
S.E.	56.7	50.6	48.6	52.6	81.3	15.0	4.5	4.4	3.3	21.2	0	0

Figure 8. Distance of gray whales offshore Piedras Blancas as a function of time, 1980. Horizontal line = mean; vertical bar = 95% C.L.; horizontal dots = median; vertical lines = range. (Source: Poole 1984).

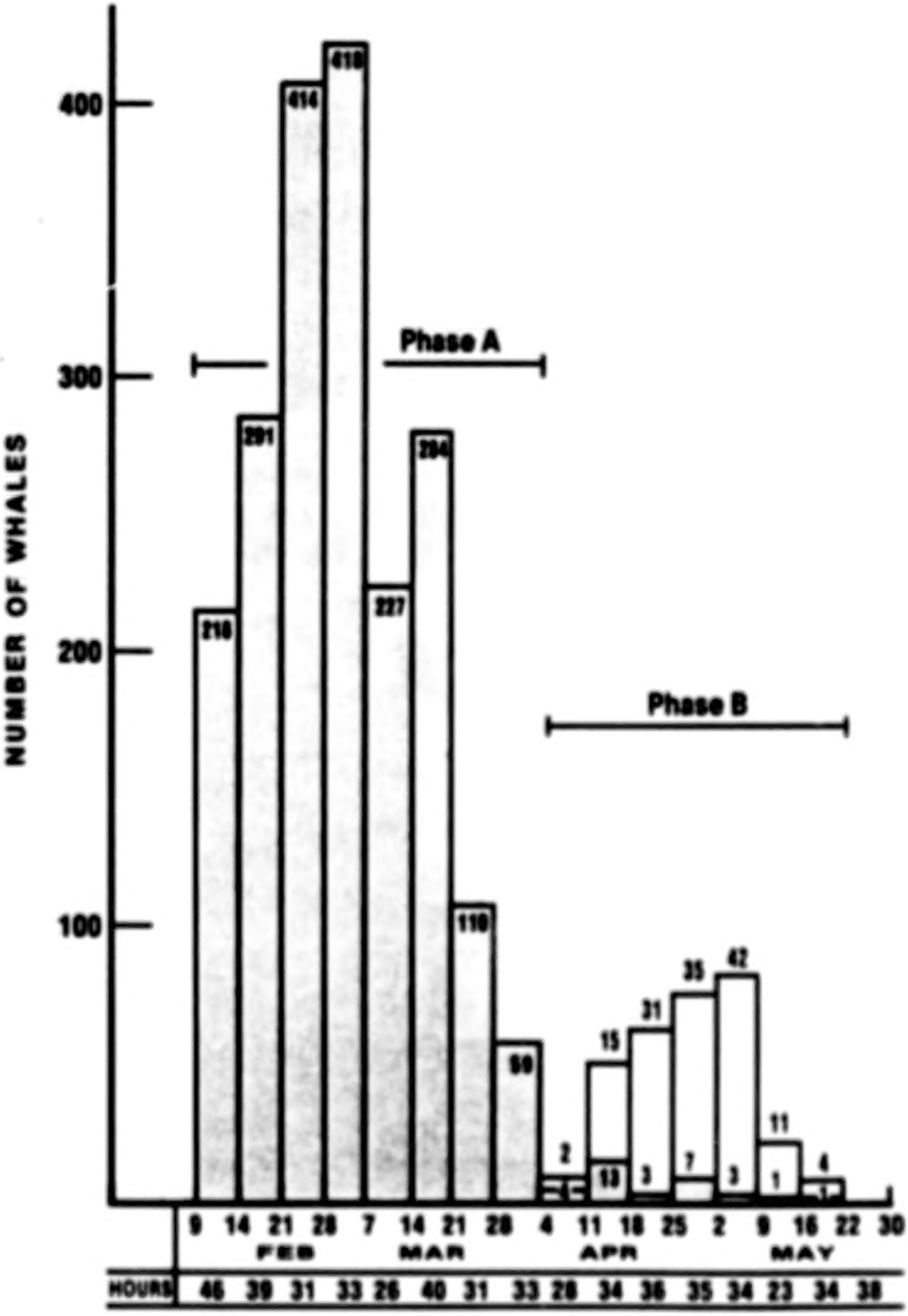
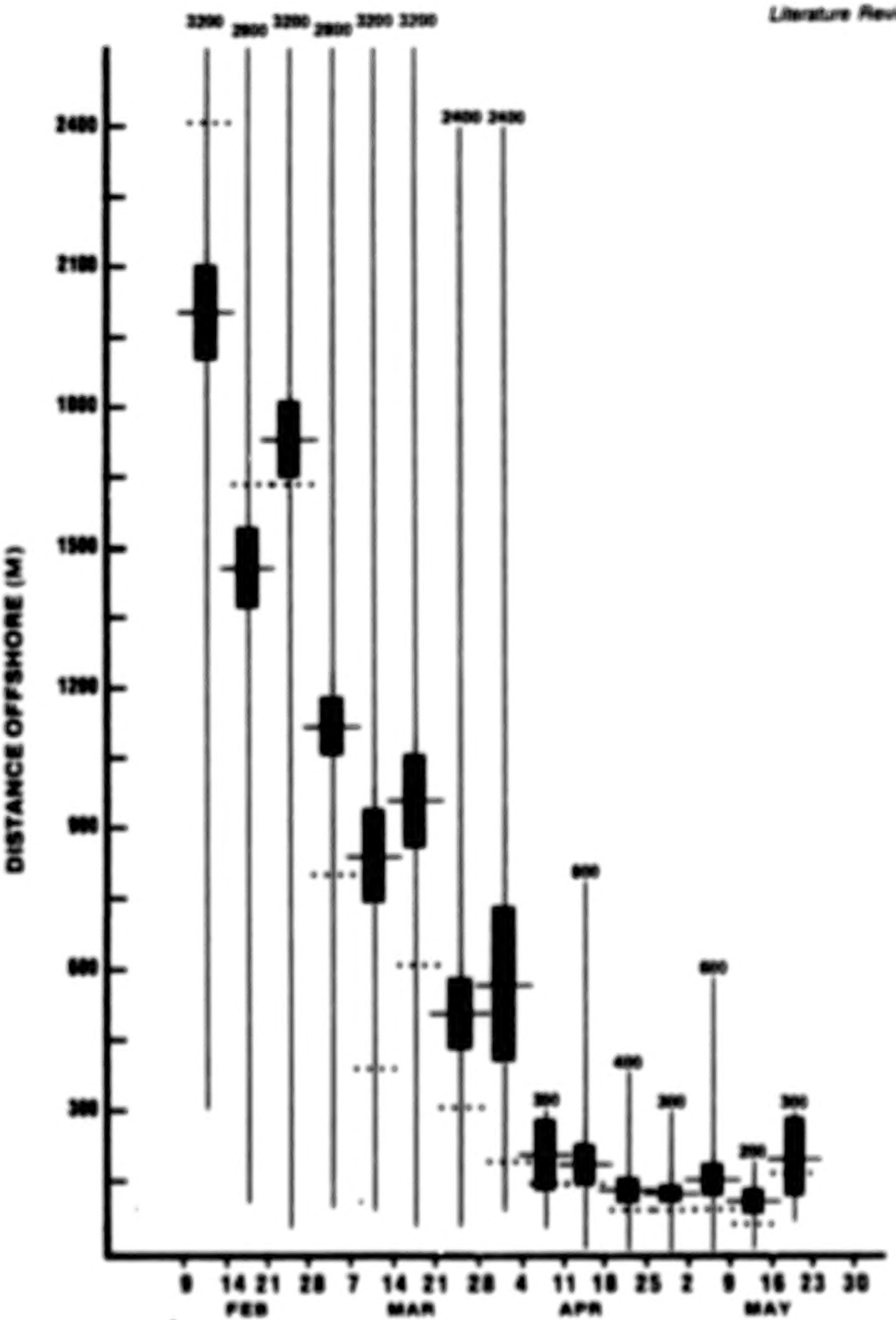


Figure 9. Weekly counts of northbound, Phase A and Phase B gray whales past Piedras Blancas in 1981. Solid bar = individuals; open bar = cow/calf pairs. (Source: Poole 1984).



Number of Whales	218	291	414	418	227	284	118	59	8	43	65	77	87	23	9	0
S.E.	52.2	42.9	40.9	31.5	49.3	49.3	36.4	82.1	32.6	29.4	5.8	6.7	14.2	12.4	36.6	0

Figure 10. Distance of gray whales offshore Piedras Blancas as a function of time, 1981. Horizontal line = mean; vertical bar = 95% C.L.; horizontal dots = median; vertical lines = range. (Source: Poole 1984).

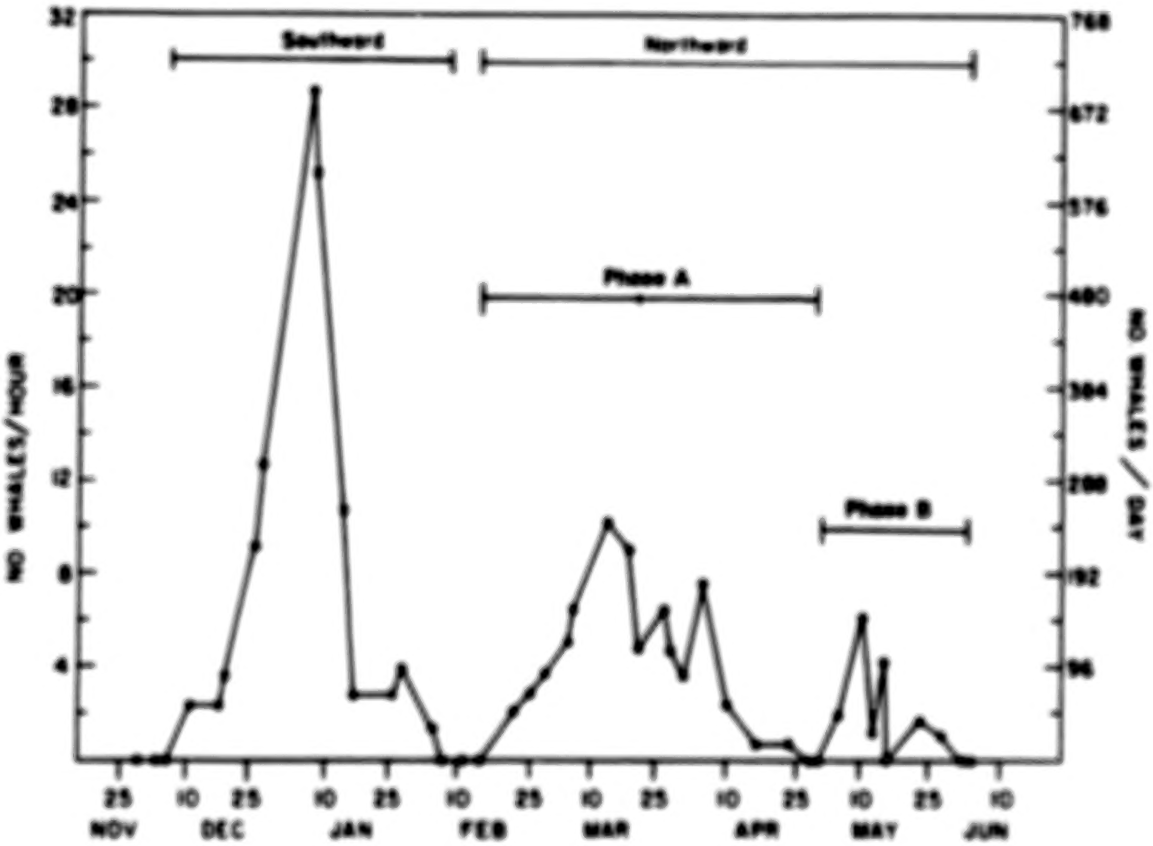


Figure 11. Timing of the southbound and northbound (Phase A and Phase B) migrations past Yaquina Head Lighthouse, Oregon, 1979-1980. (Source: Herzing and Mate 1984).

During Phase A of the northbound migration, most pods of all sizes were between 1.6 and 3.2 km offshore of Yaquina Head. Significantly fewer pods of four or more were observed within 1.6 km of shore than between 3.2 and 4.8 km offshore (Herzing and Mate 1984). In addition, small pods were closer to shore early in Phase A than later, whereas large pods were further from shore in early Phase A than in late Phase A. Over 97% of cow/calf (Phase B) pairs were within 800 m of shore during both survey years. In general, pod size decreased and whales traveled progressively closer to shore throughout the northbound migration.

Washington State

Pike (1962) summarized observations of gray whales made along the Washington coast between 1958 and 1960. Most sightings were made opportunistically from lightships or research vessels engaged in other studies. In general, gray whales off Washington appear to travel close to shore, moving between headlands, and cutting directly across the mouths of embayments.

Between 12 March and 11 April 1958, northbound gray whales were seen on several occasions along Destruction Island; most were 9.3 to 18.6 km offshore. In 1959 gray whales were seen almost every day between 15 March and 29 April from the Umatilla Lightship, 8.3 km off Cape Flattery. Many of these individuals were so close to shore that they were difficult to detect against the breaking surf. Peak numbers were seen between 28 March and 12 April. Numerous northbound gray whales were also observed between Destruction Island and Gray's Harbor from 6 April to 22 April of the same year, and on 5 April 1960 they were seen both inside and outside of Destruction Island (Pike 1962).

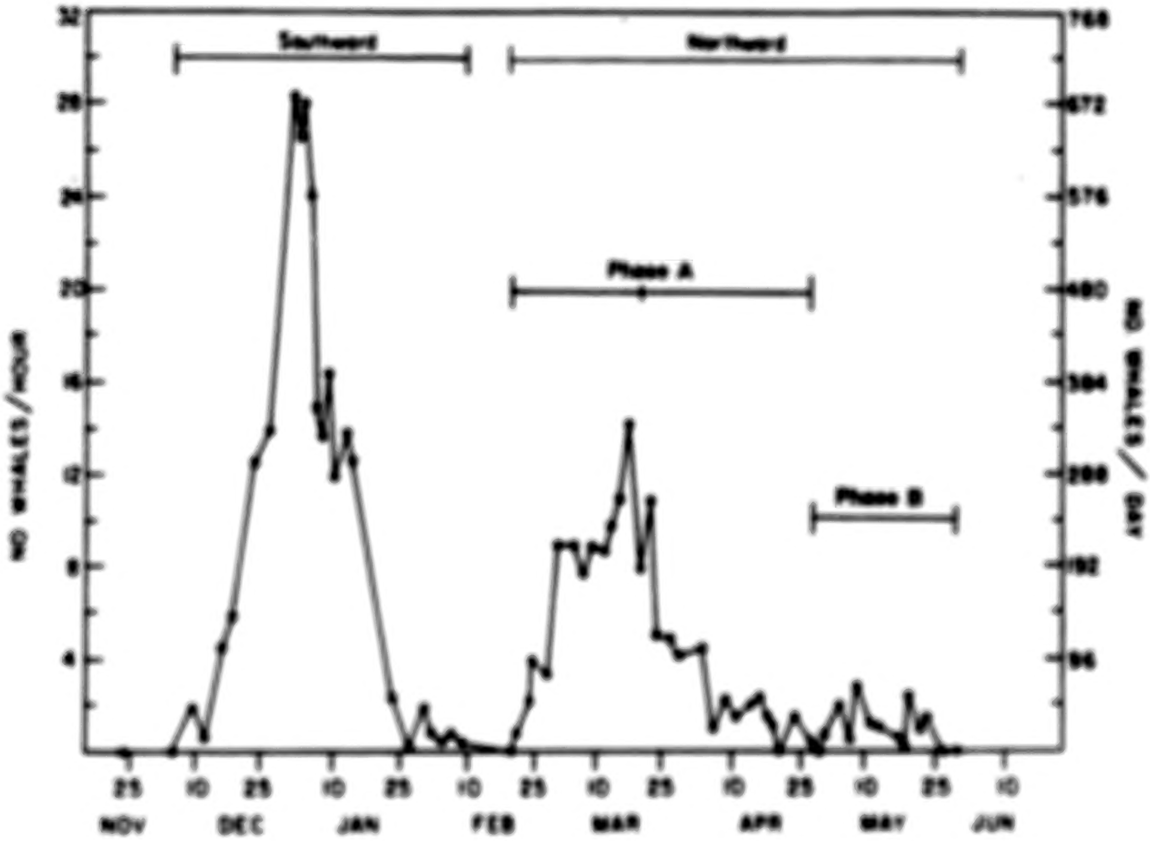


Figure 12. Timing of the southbound and northbound (Phase A and Phase B) migrations past Yaquina Head Lighthouse, Oregon, 1980-1981. (Source: Herzing and Mate 1984).

On 24 April 1959, over 200 northbound gray whales, in pods of 1 to 4 individuals, were seen 9.3 to 27.9 km offshore, between Destruction and James Islands. On the following day they were numerous off James Island (in 20 fms of water) to a distance of 16.7 km offshore (Wilke and Fiscus 1961). Gray whales were observed off Cape Flattery in May of the same year (Gilmore 1960).

Vancouver Island, British Columbia

After leaving the Washington coast at Cape Flattery, northbound gray whales cross the Strait of Juan de Fuca and follow the western coast of Vancouver Island. According to Hart (1977) the northbound migration peaks off southern Vancouver Island in early April. Seventy percent of the whales observed were singles.

Large numbers of gray whales congregate along the western shore of Vancouver Island in March and April and some have been seen at the northern end of the island as late as mid-May (Gilmore 1960). They passed close to the island during both the northward and southward migrations (Hatler and Darling 1974). The nearshore path of northbound gray whales along Vancouver Island was confirmed by the fact that they are seen frequently from nearshore vessels, but not from the Swiftsure Lightship which is located 14.8 km off the coast (Pike 1962).

Farther north at Amphitrite Point, most northbound gray whales pass inshore of a buoy which is 1.9 km from shore. Northbound whales are seen from the Amphitrite Lighthouse as early as February and as late as May, but are most abundant in March and April (Pike 1962).

In 1958, gray whales were seen off Long Beach and in Barkley Sound, Vancouver Island almost every day between 14 March and 30 April, but none was more than 3.7 km from shore. Still farther north along Vancouver Island, northbound whales passed Kains Island Lighthouse primarily during mid-April, usually quite close to shore (Pike 1962).

Hatler and Darling (1974) indicated that the peak northbound migration past Vancouver Island occurred during the first two weeks of April. Between 1972 and 1977 the northern migration past Vancouver Island began in mid-February, peaked during the last two weeks of March, and was essentially over by the end of April (Darling 1984). All sightings (from light stations) were within 4 km of shore, most were within 1 km, and many were within 100 m. As the northbound migration shifted from Phase A to Phase B, a greater percentage of whales traveled closer to shore (Darling 1984). During Phase B, over 97% of all whales seen were within 0.8 km of shore.

Gulf of Alaska

According to Braham (1984b), most northbound gray whales follow the coast from southeast Alaska to Nunivak Island in the eastern Bering Sea, staying within 2 km of shore except as they cross major bays, straits, and inlets. Gray whales have been seen in summer in the Gulf of Alaska and southeastern Bering Sea, areas well south of the traditional feeding grounds. Braham (1984b) suggests that these may be a combination of Phase B, northbound migrants and summer residents. In May 1958, eight gray whales were seen between Kodiak and Ugak Islands, suggesting that some individuals enter the Bering Sea through passes in the eastern Aleutians (Wilke and Fiscus 1961).

In the Gulf they migrate primarily within 400 m of shore and have not been seen more than 5 km from the coast. Gray whales are known from the northeast Gulf of Alaska in March, and begin going through Unimak Pass in April (Hall *et al.* 1977). Brueggeman *et al.* (1987) observed that the northbound Phase A migration along the south side of the Alaska Peninsula is coastal, 92% of the pods seen being within 7.4 km of shore. Although northbound gray whales were also observed along the south shore of Kodiak Island, the precise route between Kodiak Island and the Peninsula is still unknown.

In 1980, peak numbers of gray whales passed through Unimak Pass into the Bering Sea in the last week of April (Hessing 1983). Early in the season almost half of the whales seen were more than 500 m from shore; later in the season about 90% of the whales are within 100 m of the coast. No gray whales were seen (from land or by air) more than 1.5 km from shore. The number of small whales (presumably yearlings) increased during the second half of the study. Cow/calf pairs were first observed in early May and were always within 150 m of shore (Hessing 1983).

BEHAVIOR

Offshore oil and gas exploration and development activities may affect aspects of gray whale biology other than their migratory corridors. The following sections review literature which deals with other behavioral aspects of gray whale natural history which may potentially be affected by offshore oil and gas operations.

FEEDING

Between May and late October of each year, most of the California gray whale population is found feeding in the Bering, Chukchi, and Beaufort Seas. The gray whale is primarily a bottom feeder and amphipods are the main prey item (Oliver *et al.* 1983, Oliver and Slattery 1985). In these major feeding grounds, gray whales feed in relatively shallow water, generally less than 50 m deep. One or two amphipod species (especially *Ampelisca macrocephal*, *A. eschricti*, *Byblis gaimardi*, or *Haploops* sp.) often comprise 90% of the contents of an individual stomach, generally reflecting the composition of the benthic infauna in the feeding area (Nerini 1984).

Until fairly recently it was commonly thought that migrating gray whales do not feed. Rice and Wolman (1971) indicate that they seldom if ever feed in their wintering (calving) grounds and rarely do so along the southern portions of their route. However, Hatler and Darling (1974) suggested that gray whales will feed in any suitable habitat (shallow water and dense aggregations of benthic prey), but that such habitat is uncommon south of the Bering Sea and rare off California where early observations of whales were made.

Nerini (1984) lists 42 instances of presumed gray whale feeding behavior outside their major feeding grounds in the Arctic, and although the only irrefutable proof of feeding is stomach content analyses, the cited observations were made by experienced cetacean observers and are thought to be accurate. Thus, while gray whales do feed primarily on dense benthic aggregations in shallow, northern seas, they supplement their diet with bait fish and pelagic prey in southern waters, including resources in and near the breeding lagoons (Nerini 1984).

Nerini (1984) also notes that, while benthic resources are consumed throughout the migratory corridor, there seems to be more consumption of pelagic prey in the southern part of their range. Small gray whales have been seen feeding around kelp beds, presumably on mysids; adults have been observed feeding on pelagic prey such as small schooling fish and crab larvae.

Darling (1984) reported gray whales feeding at numerous locations along Vancouver Island and stomach contents analysis of two individuals from off Washington and British Columbia (Pike 1962) showed that northbound gray whales occasionally feed enroute, mainly on benthic amphipods. In 1982 and 1983, gray whales summering off the west coast of Vancouver Island fed heavily on dense beds of ampeliscid amphipods (Oliver *et al.* 1984). It was estimated that a small (8 m long) whale consumed 116 kg of infauna per 12 hrs.

Side-scan sonar records of gouges in the seafloor off northern California strongly resemble gray whale feeding pits in the Northern Bering Sea. The orientation and distribution of the gouges suggest that the whales are testing the benthos for food, or feeding opportunistically, but not intensely as they do in the Arctic (Cacchione *et al.* 1987).

In early August, 1981 gray whales were observed in the vicinity of kelp (*Nereocystis leutkeana*) beds off Vancouver Island (Murison *et al.* 1984). The whales' dive pattern consisted of several brief (approximately 12 sec) dives, followed by dives up to 3 min long, during which feeding took place. Epibenthic plankton hauls in the area collected two species of mysids, primarily *Holmesimysis sculpta*, and underwater observations verified dense aggregations of mysids near-bottom. Collections of fecal material from behind feeding whales contained abundant mysid exoskeletons. Surface feeding behavior by a 6 m long, juvenile gray whale was observed in 1976 in a kelp bed (Macrocystis) near Santa Barbara (Wellington and Anderson 1978). The whale appeared to be consuming small mysids.

Signs of feeding -- a muddy slurry trailing from the mouths of animals milling about in shallow water -- were seen during aerial surveys off central and northern California from 1980 to 1983 (Dohl et al. 1983). Instances of this behavior during the northern migration appeared to be more site-specific than during the southbound leg. Cow/calf pairs and adults exhibited feeding behavior during two- to three-day periods in the waters of and adjacent to Carmel Bay. This occurred with enough regularity the first two years that it was predictable in April and May of the final survey year (Dohl *et al.* 1981a). Malme *et al.* (1983) observed similar "sand streaming" from a number of calves offshore the Monterey Peninsula in 1983. An inspection of the area by divers revealed no potential prey in the water column or the upper 10 cm of sediment.

Pods of three and four adults were observed feeding on schools of small bait fish offshore Monterey (Sund 1975). The groups of whales swam in circles beneath and around a school of fish; to feed, an individual rose up through the school with its mouth agape, engulfing numerous fish.

SWIMMING SPEEDS

Early estimates of gray whale swimming speeds were based on the known distance between observation points and the elapsed time between the passage of peak numbers of whales past those points. Such techniques allowed both Gilmore (1960) and Pike (1962) to calculate the speed of southbound whales at approximately 7.4 km/hr between British Columbia and San Diego, and northbound whales at about

3.7 km/hr. Pike felt that the slower northward rate was due to frequent interruptions for feeding or resting. Later techniques which provided for the tracking of individual whales produced more accurate estimates of speed and a measure of the variability.

Southbound Migration

Wyrick (1954) followed four individual gray whales as they swam south between La Jolla and San Diego and later plotted the positions where they surfaced and blew. Three of the individuals were tracked for 5.6 to 7.4 km, the other for about 18.5 km. The speed between successive blows ranged from 2.4 to 11.8 km/hr and the average speed of the four individuals over their entire tracks was about 8.5 km/hr.

Sumich (1983) used a theodolite to track the positions of 74 southbound whales off Point Loma, California and calculated a mean swimming speed of 7.2 km/hr. Malme *et al.* (1983) observed the southern migration off Soberanes Point (approximately 22 km south of Monterey) in 1983, and estimated swimming speeds of 5 to 10 km/hr. Cummings *et al.* (1968) used an array of hydrophones to track nine southbound whales off San Diego and obtained an average speed of 10.2 km/hr. Monitoring at night revealed that gray whales make about as much noise at night as during the day, suggesting that they do not stop at night to rest or sleep.

According to Rice and Wolman (1971) the lack of consistent hourly variation in the numbers of gray whales passing shore stations suggests that the southbound whales maintain a fairly constant velocity during daylight hours. However, on the basis of Pike's (1962) estimate that gray whales travel 185 km per day during 10 hrs of daylight, Rice and Wolman (1971) calculate that they must travel 100 km during 14 hrs of darkness. Thus, gray whales are estimated to travel 7.7 km/hr during the day and 7.1 km/hr at night.

Mate and Harvey (1984) used data from other studies on the timing of peak numbers of whales passing study sites during the southbound migration and determined that the data support Pike's (1962) contention that gray whales move faster during the southbound migration (approximately 125 km/day from Unimak Pass, Alaska to Monterey, California) than when they migrate north (approximately 88 km/day from Piedras Blancas to Unimak Pass). Mate and Harvey (1984) suggest that the slower swimming speeds observed off southern California and Baja California may be a result of mating and suckling activities which occur there more often.

Northbound Migration

The northbound migration is composed of two temporally separate, but overlapping, phases and the time interval involved is about twice that of the southbound migration. Calculation of an average speed for northbound migration may be misleading since the first phase is composed of single adults, while the second phase is cow/calf pairs. The latter typically follow the coastline closely and while their speed at a given moment in time may be the same as a single traveling adult, calculation of speed based on the distance made good over a straight line may be lower.

Leatherwood (1974) estimated the swimming speeds of individual, northbound gray whales. Three animals, identified by distinct, natural markings, were spotted on two or three separate days and their positions were plotted to establish the straight-line distance they had traveled in the known time increment. The three individuals moved at average rates of 2.6, 2.8 and 2.9 km/hr.

Mate and Harvey (1984) radio-tagged four females with calves and three single adults in San Ignacio Lagoon, Mexico and tracked their northward migration paths and speeds. The minimum average daily swimming speeds (in the open ocean) for the singles were 1.1, 1.4, and 1.3 km/hr. Two of the females with calves actually had higher rates of travel than the singles, with minimum daily speeds of 2.2 and 1.5 km/hr. The remaining females averaged 0.7 and 1.2 km/hr.

One single adult was relocated five times between San Ignacio Lagoon and Unimak Pass and its record supports the suggestion that northbound gray whales travel more slowly in the southern portions of the migration corridor (Mate and Harvey 1984). This individual averaged 1.4 km/hr between San Ignacio Lagoon and San Diego; 3.4 km/hr between San Diego and Coos Bay, Oregon; 4.2 km/hr along the Oregon coast; and 5.3 km/hr (2.86 knots) between Oregon and Unimak Pass.

At Point Sal, California (Section II of this report) 53 cow/calf pairs averaged 5.0 km/hr, with individual pairs traveling between 1.8 and 7.7 km/hr.

RESPIRATION

Although many studies have investigated respiration rates and diving patterns in the calving lagoons, relatively few studies have addressed these aspects of gray whale behavior during their migrations.

While migrating, whales surface regularly every 3 to 5 min to blow 3 to 5 times (Rice and Wolman 1971). Wyrick (1954) noted that the breathing cycle of southbound migrants was between 4 and 5 min, consisting of three quick blows followed by a long dive. He also reported that when the research vessel came to within 183 to 274 m ahead of a whale, the whale would veer to one side until well clear of the ship, then resume its course.

An attack by seven killer whales on three northbound gray whales (including a cow/calf pair) was observed in May 1967 near the Moss Landing Marine Laboratory (Morejohn 1968). While being pursued, their respiration rate increased with blows every 60 to 80 seconds. After the incident, the respiration rate of cow/calf pair decreased to blows every 4 to 5 min.

Sumich (1983) found that 11 southbound whales had an average respiration rate of 0.72 breaths per minute and that their surfacing and dive duration patterns were of two distinct types. Short dives of less than 1 minute accounted for approximately two-thirds of the total, whereas most of the remaining dives were longer than 2 min. Typical surfacings patterns exhibited by migrating gray whales included 2 to 4 successive surfacing and blows 20 to 30 seconds apart followed by a dive of several minutes. The long dives may be an adaptive strategy which permits extensive swimming at depths below significant surface drag effects (Sumich 1983).

Sumich (1983) also compared the diving patterns of 4 whales swimming at less than the overall mean speed of 7.2 km/hr with those of 7 whales swimming faster than the mean. The faster whales had higher breathing rates, which they attained by decreasing the mean duration of their long dives to just over 3 min, not by making more short dives. By comparison, the slower whales had a mean long dive of nearly 4 min.

REPRODUCTION

The lagoons and nearshore waters of Baja California and the Gulf of California are traditionally considered to be "calving and mating" grounds of the California gray whale population (Gilmore 1960). While the majority of these two activities may take place there, there is evidence that both also occur during migrations and in the summer feeding grounds. Rice and Wolman (1971) indicate that the courting and copulation which take place in the calving lagoons coincide with the second estrous cycle of females. This would only happen with females not impregnated during their first cycle, thus suggesting that it only occurs when impregnation has not occurred during migration.

Courtship and suspected mating having been observed throughout both northbound and southbound migration corridors. Gilmore (1960) observed that groups of two or three individuals are commonly seen courting or mating while enroute in January. Possible mating in a pair of gray whales was observed off Vancouver Island in April, 1971, although actual copulation could not be confirmed (Hatler and Darling 1974). Wilson and Behrens (1982) observed sexual behavior in two separate pods (one of 2 and one of 3 individuals) during the northbound migration off San Luis Obispo County, California.

While most calves are born in the shallow lagoons in Mexico, some are also born during migrations (Rice and Wolman 1971). Sund (1975) observed a cow/calf pair moving south off Monterey in 1973. During three years of aerial surveys in the Southern California Bight (1976 to 1978), Dohl *et al.* (1981b) observed a total of eight juveniles of a size that would indicate that they were born in the Bight.

Yochem *et al.* (1986) reported 12 newborn calves in 1981 and 7 in 1983 between the mainland coast and the northern Channel Islands. His summary of observations (from 1955 to 1985) of newborn, southbound gray whales between San Francisco and the Mexican border indicate that calves have been born successfully during migration for at least 30 years.

Malme *et al.* (1984) observed 15 cow/calf pairs off Monterey in 14 days of observations of the southbound migration. In 37 days of observation (January 1986) at Granite Canyon, 25 calves of the season were observed (M. Dahlheim, pers. comm., as cited in Jones and Swartz 1987).

Aerial censuses of gray whales in the Channel Islands National Marine Sanctuary encompassing the islands of San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara) were conducted during the southbound migration in January and February, 1986 (Jones and Swartz 1987). A total of 17 calves was sighted, representing 13.3% of the total number of gray whales.

SUMMARY AND CONCLUSIONS

1. Recent estimates of the California gray whale population are based on shorebased censuses with aerial verification of the proportion of whales which pass offshore. An estimate made in 1986 places the population at 18,500, plus or minus 2,000 individuals. There is no doubt that the gray whale population has expanded since it was afforded protection in 1946 and apparently it is continuing to grow.

2. On their southbound migration, gray whales leave the Bering Sea through Unimak Pass between October and December of each year. This migration constitutes a single pulse. The whales follow the coast through the Gulf of Alaska down the Pacific Coast to Mexico. Although most gray whales stay within several kilometers of shore, they do tend to travel farther offshore across bays and bights. The southern migration occurs over a period of about two months and peak numbers of gray whales pass landfalls at relatively predictable times.

3. The northbound migration departs Mexican waters in March and April. The first phase includes mostly adult and subadult animals. The second phase includes primarily females with recently-born young ("cow/calf pairs"). The first phase tends to swim further offshore than the second, skirting from headland to headland. Cow/calf pairs tend to travel within several hundred meters of the coast. The northward migration occurs over a period of about four months, and the arrival of peak numbers at particular locations is less predictable.

4. Gray whales feed primarily on benthic amphipods in Arctic seas. There is increasing evidence that some feed during the migration and that pelagic prey may also be consumed.

5. Southbound whales moved at rates ranging from 7.1 to 10.2 mph. Northbound whales swam at rates ranging from 0.7 to 5.3 mph. Northbound rates were lowest in the southern waters and increased as the animals moved northward.

6. Relatively few observations of respiration rates and dive times have been conducted on migrating gray whales. Typical surfacing patterns include 2 to 4 successive surfacings and blows 20 to 30 sec apart followed by a dive of several minutes.

7. Historically, most mating and calving was thought to take place in the lagoons of Baja California and the Gulf of California. Births do occur during the southern migration. Sexual activities have been observed along both northbound and southbound migratory corridors. There is even the suggestion that mating in the lagoons involves females which were not impregnated during the southbound migration.

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SECTION II

GRAY WHALE MIGRATION FIELD SURVEY

INTRODUCTION

This section presents the results of observations made during migrations in 1986, 1987, and 1988 to record gray whale movements and behavior as they passed Point Sal, Santa Barbara County, California. The study site was selected by the Minerals Management Service to provide a shorebased observation point that would overlook the proposed site of Platform Julius. At the initiation of the study, Platform Julius was scheduled for installation in 1987-1988. At present, this schedule has been delayed for an indefinite period of time. Therefore, the database assembled represents pre-installation background and can be utilized for post-installation comparison, if and when the platform is installed. Based upon the experience of the investigators during this study, recommendations for future monitoring programs are provided.

The project study area is located on the mainland shelf of south central California, on the eastern margin of the Santa Maria Basin, approximately 53 km north of Point Conception (Figure 13). Water depth ranges from the intertidal to over 550 m. Between shore and the proposed Platform Julius site, the shelf is relatively narrow and regular with an average slope of less than 0.5 degree.

Platform Julius, the first oil platform scheduled to be constructed as part of the San Miguel Project (URS 1985), will be located in the northwest quadrant of Lease OCS-P049 (Figure 13), 15.3 km west of Point Sal at a water depth of 146 m. Three subsea pipelines will be constructed from the platform to onshore processing facilities 929 m north of the Santa Maria River. These pipelines will carry oil/water emulsion, produced water, and service fuel between the platform and the processing facility (URS 1985).

The purpose of this study was to describe baseline characteristics of the gray whale migration prior to offshore oil and gas development. The accumulation of data was influenced by numerous factors, especially the number of allotted sampling days and the number of whales passing the observation post on these days. The study was not intended to census the entire whale population in the area; thus, whale and pod abundances and rates of sightings, are given primarily to provide background. Because the number of whales passing a point in a given migration generally is low initially, gradually increasing to a peak, and then decreasing (Breiwick and Dahlheim 1986), inter-regional comparisons of sighting rates are not meaningful unless similar portions of the migration are studied.

The selection of Point Sal as a study site is supported by the following: 1) past aerial surveys of the central California coastline (Dohl *et al.* 1983) which indicate that Point Sal is within the migratory pathway of the gray whale; 2) census work north of the Santa Maria Basin near Monterey (Reilly *et al.* 1983, Breiwick *et al.* 1985, Breiwick and Dahlheim 1986), Diablo Canyon (Behrens 1983, Behrens *et al.* 1984, Behrens *et al.* 1985, Behrens 1987) and immediately to the south in the Channel Islands (Jones and Swartz 1987a) which document the passage of substantial numbers of the gray whales north and south of Point Sal; and 3) the absence of documented alternate routes which bypass the Santa Maria Basin.

Malme *et al.* (1983a, 1984) and Richardson *et al.* (1983) indicate that short-term changes in gray whale swimming speed and direction of movement may result from human activities. Malme *et al.* (1983a, 1984) showed that the broadcast of tape recorded noise from various oil and gas industry activities elicited responses from migrating gray whales offshore Soberanes Point, near Monterey, California. Drillships and seismic arrays elicited responses from whales at distances as great as 1.1 and 2.5 km, respectively. These may be more important (from the standpoint of affecting migration behavior) than are drilling and production

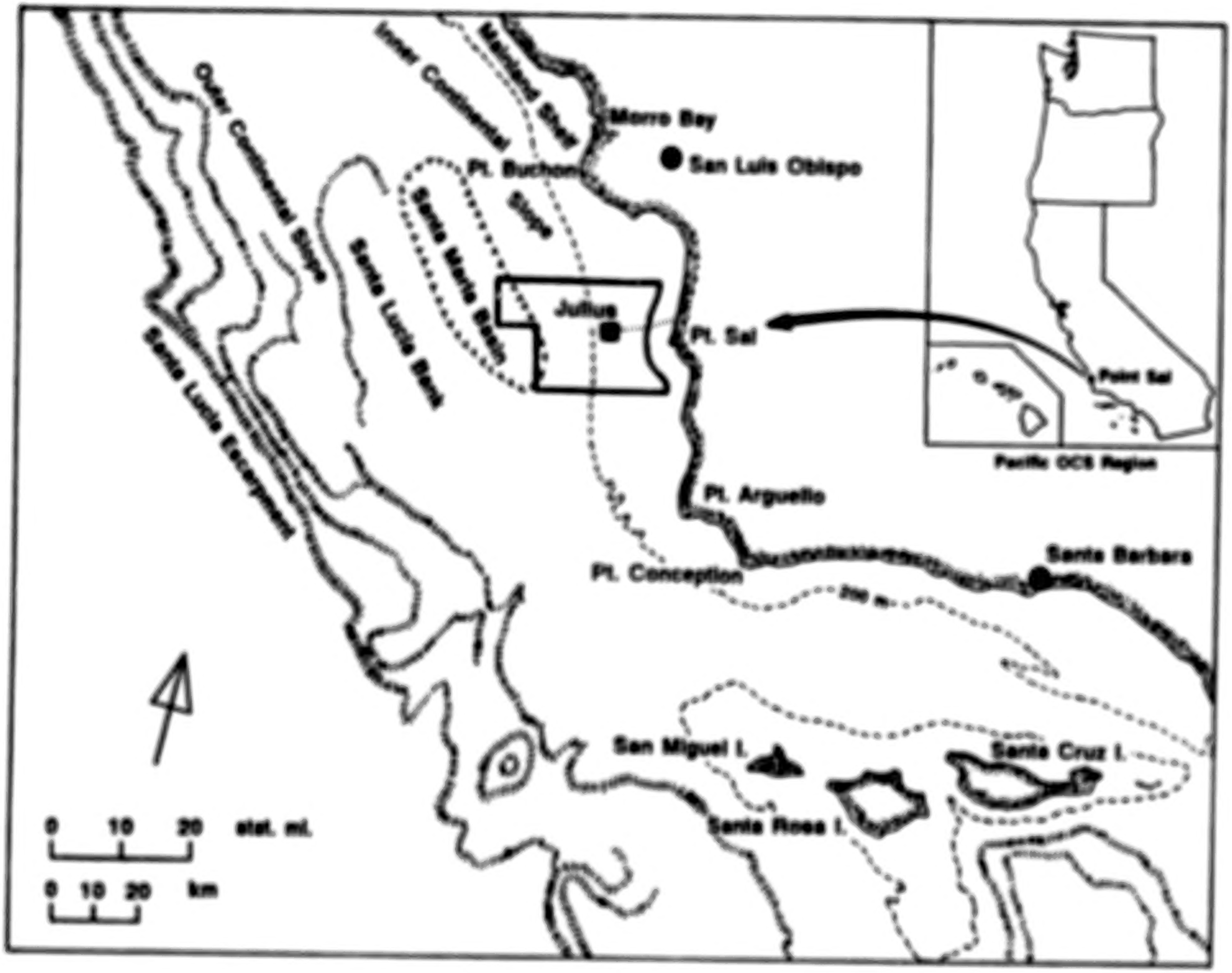

Figure 13. Location of the study area, in the vicinity of Point Sal, central California. Blocked area represents limits of the San Miguel Project.

platforms, semi-submersible rigs, or helicopters, which appear to have only short-range effects. The responses to noise included short-term "startle" reactions, slowing down, and changing course around the noise source. Whales, however, seemed to habituate to the noises. Because the gray whale migration corridor overlaps with potential oil and gas lease areas in the Santa Maria Basin, it is important to establish the normal range of gray whale behavior prior to industrial activities.

MIGRATION ROUTE OF THE GRAY WHALE

The gray whale, also known as the Pacific gray whale (*Eschrichtius robustus*; Lilljeborg 1861) is generally believed to be the last of three historical populations. The north Atlantic and western Pacific (Korean) populations are believed to have been hunted to extinction in the early days of hand whaling.

Since receiving international protection in 1947 when its numbers were estimated at 4,000 to 5,000 individuals (Wolman and Rice 1979) and United States federal protection under both the Marine Mammal Protection Act (1972) and the Endangered Species Act (1973), the gray whale has made a remarkable comeback from near extinction in the mid to late 1800s. Recent estimates indicate a population increase from approximately 11,000 in 1966 to 17,577 in 1979-1980 (Blokhin *et al.* 1985, Mead and Mitchell 1984, Reilly *et al.* 1983, Wolman and Rice 1979) and up to 18,500 in 1984-1985 (Breiwick *et al.* 1988).

Each year most gray whales migrate more than 12,000 km (round-trip) from summer feeding grounds in the Bering and Chukchi Seas to breeding, calving, and nursery grounds in Mexico. Figure 14 shows the Oregon and California region of migration and lists locations of some of the areas discussed in the text of this report. These annual migrations are generally predictable in terms of where and when whales can be expected (Dohl *et al.* 1983). Gray whales migrate through southern California from November to early June of each year. In central and southern California, southbound animals are seen from November through early March with peak numbers between late December and mid-January. During February and early March the migration is actually a mix of late southbound and early northbound whales. From March through June virtually all individuals are northbound. Some whales apparently do not make the trip to the Baja lagoons, but winter-over along the northern California coastline (Dohl *et al.* 1983), the Channel Islands National Marine Sanctuary (Jones and Swartz 1987b), and along the southern California coast (Dohl *et al.* 1981b).

The ability to accurately observe gray whale behavior may be critical in determining if the installation and operation of a platform and pipeline has altered "normal" migration patterns. Platform installation and vessel or aircraft activity may potentially alter the dive time, respiration rate, swimming speed, and other behaviors in addition to the migration corridor. The behaviors that gray whales may exhibit during migration are listed in Table 2. Those most readily quantified include distance from shore, swimming speed, dive time, and respiration rate.

THE SOUTHBOUND MIGRATION

The southbound migration constitutes a broad wave of animals which lasts about 60 days, between late December and early February (Pike 1962, Rice and Wolman 1971, Reilly 1981, Breiwick and Dahlheim 1988). Rice and Wolman (1971) determined that the order of southbound migrants consisted, in order, of the following groups: 1) near-term females, 2) recently ovulated females, 3) adult males and immature females, and 4) immature males. Jones and Swartz (1987a) reported simultaneous occurrences of different age, sex, and reproductive status groups in late January 1987, and speculated that the southward migration in the Channel Islands National Marine Sanctuary may be more complex than in the San Francisco area, where Rice and Wolman (1971) reported the segregation based on age, sex, and reproductive status.

During the southbound migration most individuals and pods travel within a few kilometers of the coast except in the vicinity of coastline indentations and offshore islands. Herzing and Mate (1984) reported that most of the pods of four or more individuals passed the Oregon coast early in the migration, while single individuals or pods of two or three occurred throughout the migration. The larger groups also tended to migrate further offshore; most whales were between 1.6 and 3.2 km offshore, in water 40 to 60 m deep.

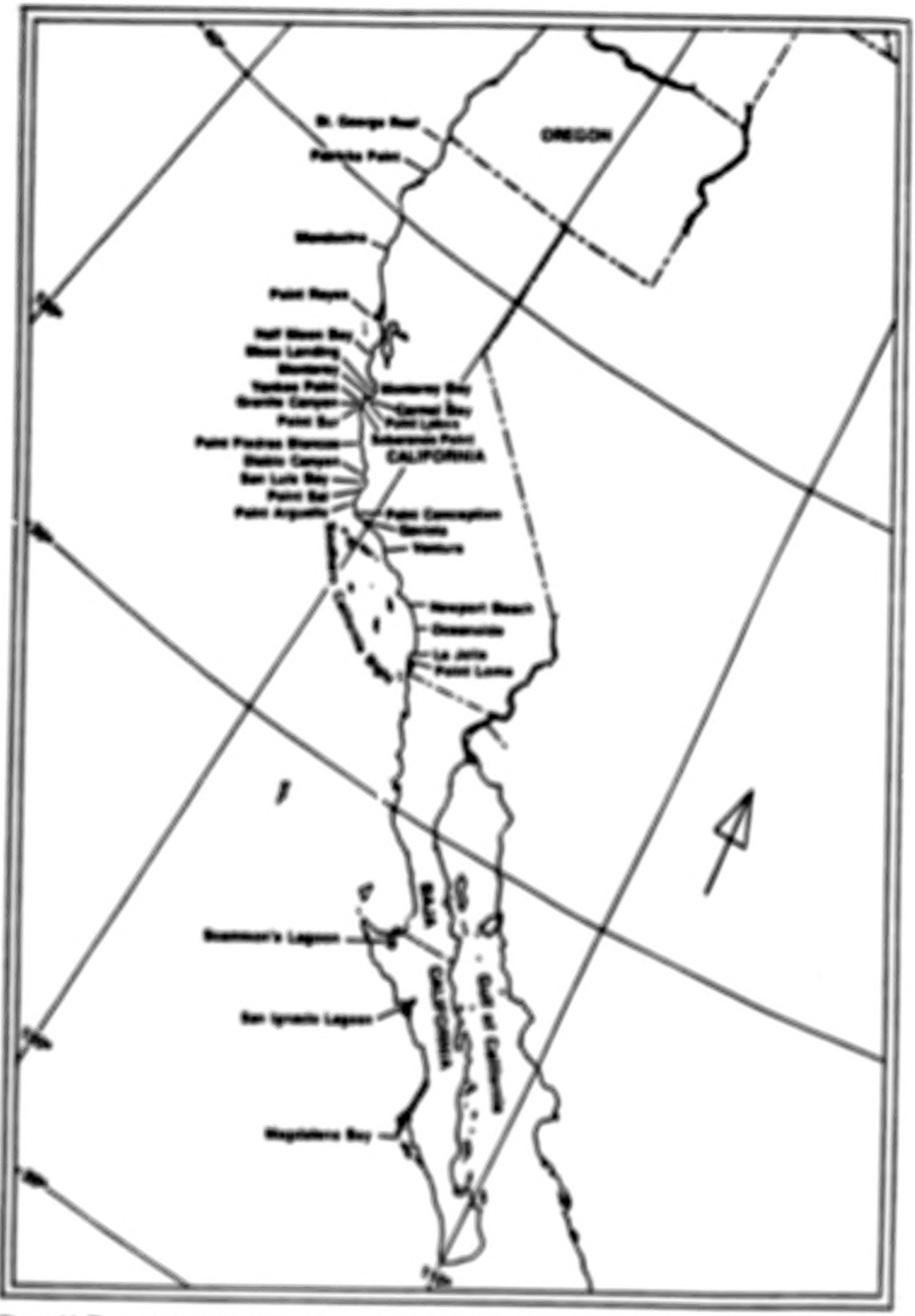

Figure 14. The central portion of the gray whale migration along the Pacific Coast and locations of study sites mentioned in the text.

In the vicinity of Monterey Bay, all migrating whales were within 11.3 km of shore, 98% within 8 km, 96% within 4.8 km, and 94% within 1.6 km of shore (Sund and O'Connor 1974). The mean distance of southbound whales offshore Yankee Point and Granite Canyon (south of Monterey) has ranged between 1.0 and 1.2 km in 1978-1979 (Reilly *et al.* 1983) and 1.8 and 2.1 km in 1984-1985 (Breiwick and Dahlheim 1986). Less than 5% of the whales observed traveled at a distance greater than 3.2 km from shore (Breiwick and Dahlheim 1986).

Table 2. Gray whale behavior definitions employed during the field surveys.

Blow Interval: The time between successive blows from the same individual.

Blow: The exhalation of air from the blow hole characterized by a spout of water/air. Mother Blow = mother in a cow/calf pair is observed blowing. Calf Blow = calf of cow/calf pair observed blowing.

Both Blow: = both mother and calf are observed blowing at the same time.

Bottom Feeding: Not directly seen; usually represented by discoloration of the water when the whale is foraging through the mud bottom.

Breaching: When a whale leaps out of the water.

Calf Inside: When a calf is traveling inshore of the mother.

Calf Outside: When a calf is traveling seaward of the mother.

Direction Changes: Movements in a direction other than the direction of migration: i.e. movement towards shore, perpendicular to the direction of migration; turning about and facing or swimming in a direction opposite to the direction of migration; any sudden course change from the direction of migration.

Dive: Subsurface swimming between two successive surfacings.

Drifting: Laying at the surface and moving with the current without actively swimming.

Fluke-up: The raising of the entire tail above the water's surface.

Frolicking: The sum set of surface-active behaviors that are associated with sexual activity, with the exception of observable intercourse.

Group Joining: When two groups converge and swim together.

Group Splitting: When two or more groups swimming together diverge and swim separately (greater than five body lengths) from each other.

Head Lift: An event when the anterior portion of the rostrum is seen above the water but not as far back as the eyes.

Head Lunge: The head of a whale comes out of the water at a 45 degree angle to the water's surface while traveling

Lob Tail: The whale raises its fluke together with a portion of the tail stock above the water and slaps it down on the surface.

Lollygagging: Moving very slowly in direction of migration. Includes "drifting" and "milling" behaviors.

Milling: When a whale or a group of whales temporarily stops moving in the direction of migration and, instead, changes direction frequently while remaining in approximately the same location.

Respiration Rate: The rate at which blows occur, assuming each blow represents exhalation following inhalation. The number of blows/total observation time.

Rolling: When a whale rotates on the long axis of its body, so that either the sides or belly of the animal are facing up.

Sexual Activity: Behaviors associated with mating including, rolling, penis extension, vertical flukes and pectorals, head ups, and tail lashes within 2+ groups of individuals, usually two males and a female. Intromission is observed.

Spyhopping: Refers to the behavior of raising the anterior portion of the body out of the water so that the eyes are above the water.

Surface Skim Feeding: When a whale opens its mouth and skims the surface of the water, presumably for prey; other surface behaviors usually occur when surface skimming is seen.

Surface: When a whale emerges from a dive, but no blow is observed.

Underwater Bubble Blast: Underwater exhalations causing a mass of bubbles to disturb the water's surface, usually in an area of several meters diameter.

Vertical Flukes/Pects Extension: Occurs when a whale rolls onto its side and a fluke tip is seen above the water's surface; this behavior may also be accompanied by an extended pectoral fin.

South of Point Conception, southbound migrants no longer follow the nearshore coastal corridor as they do to the north of Point Conception. In the Southern California Bight the majority of whales are seen in the vicinity of the offshore islands; Dohl *et al.* (1981b) report only 24% of all sightings within 9.6 km of the mainland coast.

THE NORTHBOUND MIGRATION

The northbound migration can be segregated into two temporal groups. The first phase of the northbound migration, called Phase A by Poole (1981) is composed of newly pregnant females, adult males, anestrous females, immature females, and immature males (Rice and Wolman 1971). These animals generally retrace their southbound migratory track (Leatherwood 1974a) in groups of up to 10 or 12 animals (Dohl *et al.* 1981b). The second pulse (Phase B) is composed of females with newly born calves (cow/calf pairs) which usually travel within 10 to 200 m of the shoreline.

Poole (1981, 1984) monitored the northbound migration at Piedras Blancas (approximately 170 km north of Point Conception) and noted that Phase A animals passed in peak numbers in early March. Their general path was from headland to headland, being as much as 16 km offshore near embayments and as close as 400 m near promontories. The second pulse (Phase B) consisted of cow/calf pairs and peak numbers of these passed the observation site in late April (in 1980) to early May (in 1981). During the two-year study over 96% of all cow/calf pairs observed were within 200 m of shore.

The same two northward phases have been observed further north along the California coast (Dohl and Guess 1981, Dohl *et al.* 1983). Phase A peaked in early March and the same headland to headland path was noted, with 98% of the whales less than 9.3 km from shore. Phase B reached peak numbers in late May, and these pairs were extremely close to shore, often in kelp beds or just outside the surf zone.

In summary, the migration route of gray whales is over the continental shelf and generally within 10 km of the shoreline, and thus overlaps with both present oil and gas production activities, as well as potential exploration and development activities along the coast. OCS oil and gas activities may have a cumulative impact on gray whales and could result in short- or long-term changes in the migratory pattern and/or other behavior during migration. Impacts may result from seismic surveys, platform construction, drilling operations, and surface vessels and aircraft which support the platform activities (Richardson *et al.* 1983; Gales 1982, Malme *et al.* 1983a,b,c 1984), oil spills, hydrocarbon uptake (Geraci and St. Aubin 1980, Cowles *et al.* 1981), and collisions between support vessels and gray whales (Richardson *et al.* 1983).

METHODS

Initially, the study was designed to conduct studies from shorebased observation areas only; however, because the proposed Platform Julius will be 15.5 km from the shoreline, the study design was modified to include aerial observations in order to more fully document the distribution of gray whales in the area. Aerial observations were conducted over a wide open ocean area to determine the extent of the gray whale migratory corridor. Shorebased data were collected to document nearshore gray whale distribution, direction of movement, and behavior (swimming speed, dive duration, respiration rates, and behavior).

Field surveys were scheduled on the basis of gray whale counts from various researchers between San Diego and Monterey, California, who supplied information on a weekly and sometimes daily basis. The dates of surveys, and the types of data collected for both aerial and shorebased studies are shown in Table 3.

AERIAL SURVEYS

Aerial surveys were conducted in April 1986, January 1987, March 1987, May, 1987, and March 1988 by Mr. Tom Dohl of Monterey Aero Services, Monterey, California. Weather permitting, flights were coordinated with periods of shorebased observations during each of the surveys. Survey flights were

Table 3. Survey dates and types of data collected for both aerial and shorebased studies.

	Distance From Shore	Direction of Movement	Swimming Speed	Dive Time	Respiration Rates	Behavior	Incidental Sightings	Weather Sea State
AERIAL SURVEYS								
Southbound Survey								
Jan 1987								
Non-Cow/Calves	x	x					x	
Cow/Calf Pairs	x	x					x	
Northbound Survey								
April/May 1986	A,B	A,B					x	x
March 1987	A,B	A,B					x	x
May 1987	A,B	A,B					x	x
March 1988	A,B	A,B					x	x
SHOREBASED SURVEYS								
Southbound Survey								
12,17-21 Jan 1987								
Non-Cow/Calves	x	x	x	x	x	x	x	x
Cow/Calves	x	x	x	x	x	x	x	x
Northbound Surveys								
30 Apr and 1-2, 4-6 May 1986	A,B	A,B	A,B	A,B	A,B	A,B	x	x
16-17, 25-29 Mar 1987	A	A	A	A	A	A	x	x
4-5, 11-12 May 1987			No Whales Observed				x	x
6-12, 14-18 Mar 1988	A	A	A	A	A	A	x	x
18, 25-28 Apr 1988	A,B	A,B	A,B	A,B	A,B	A,B	x	x

X = data collected
A = Phase A animals (non-Cow/Calves)
B = Phase B animals (Cow/Calve Pairs)

scheduled for both morning and afternoon of each survey day, however, afternoon northwesterly winds frequently generated sea states in excess of the maximum Beaufort 3 required for optimum observing. It is important to note that since population estimates were not an end-product of the surveys and because line-transect theory not invoked, differences in survey altitude, air speed, transect line orientation, time of day, and day of month did not in any way alter the validity of the data obtained.

The purpose of the aerial surveys was to establish the distance of migrating gray whales offshore, especially in areas directly offshore of Point Sal and adjacent to the proposed location of Platform Julius. Because data were required from within a well-defined and relatively small study area, a sampling grid consisting of a series of parallel transect lines with connecting cross-legs was established seaward of Point Sal. This grid was expected to sample the major migratory pathways between Point Sal and the proposed platform Julius.

STUDY AREA

1986

The original survey of the northbound migration was conducted on 26 April 1986 along parallel lines extending from shore on a heading of 270 degrees magnetic, seaward approximately 10 nm (1.85 km). The transect lines were centered on Point Sal with four lines to the north of the Point and four to the south

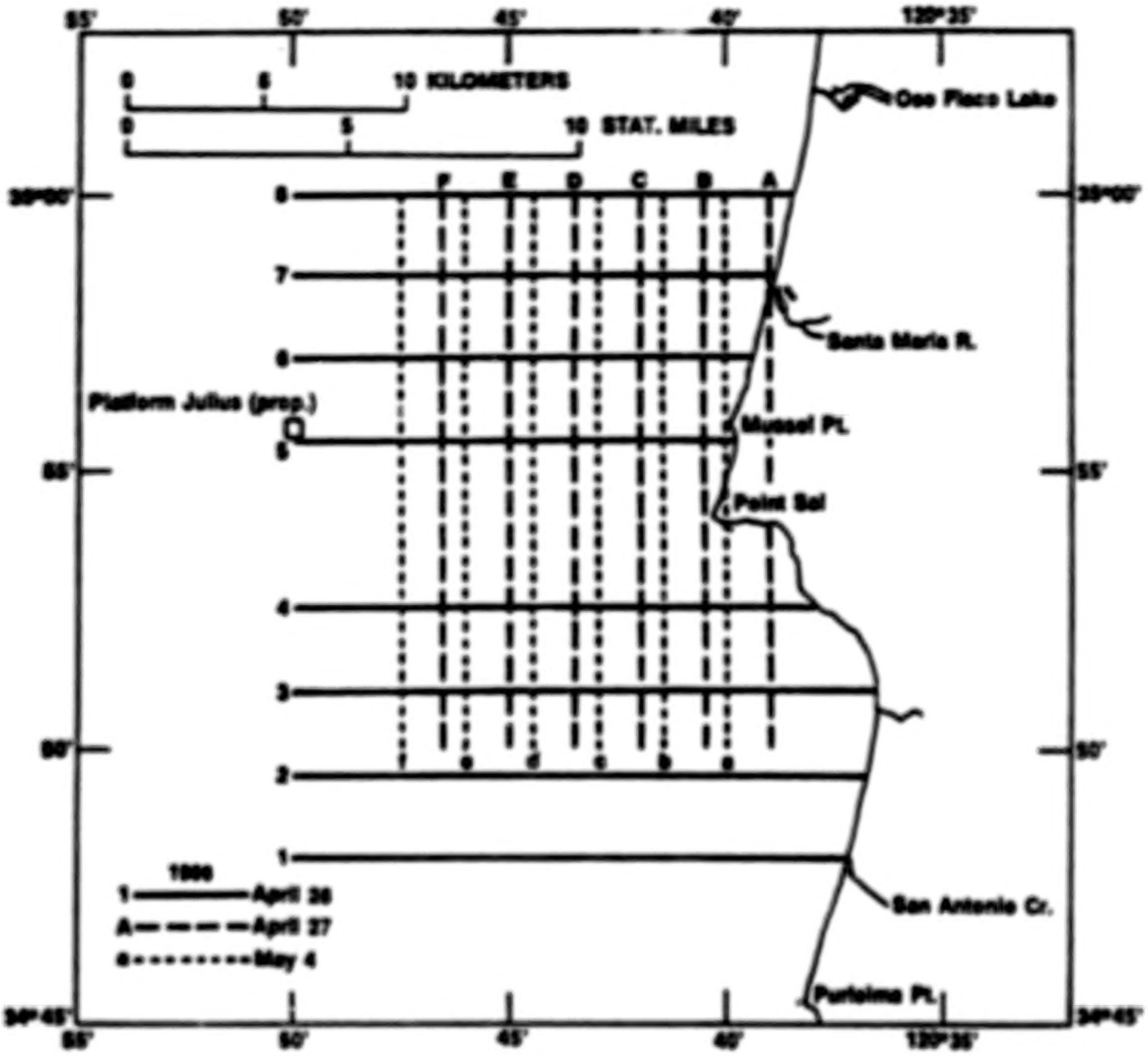

Figure 15. Location of aerial transect lines off Point Sal during northbound migration in April and May 1986.

(lines 1-8, Figure 15) each separated by 1.5 nm (2.8 km). The survey was conducted from a Boelkow helicopter flown at approximately 110 kn (204 km/hr) and an altitude of 1,000 ft (305 m) above sea level (ASL).

On the second survey day (27 April), transect lines were aligned in a north-south array, parallel to the shoreline (lines A-F, Figure 15). The survey platform was the same Boelkow helicopter, but the airspeed was reduced to 95 kn (176 km/hr) and the altitude to 800 ft (245 m) ASL . The third day of sampling (4 May) was flown in the same helicopter, at the previous day's speed and altitude, but the transect lines were offset seaward (lines a-f, Figure 15) to avoid flying an overland segment inland of Point Sal.

1987 and 1988

In 1987 and 1988, transect lines and survey protocol were standardized. Eight 15 nm (27.8 km) long north-south transects were established with 2 nm (3.7 km) spacing between the six nearshore lines and 4 nm (7.4 km) between the most seaward lines. Because numerous gray whales were sighted seaward of proposed Platform Julius site as well as north and south of the study area, the length of the transect lines and the inter-line distance were extended and transects were flown seaward to 120°00'. During northern migrations, an additional north-south transect line was added parallel to the others, passing just over Point Sal. The entire survey grid was also shifted north or south in relationship to Point Sal to optimize sighting of gray whales during their southern or northern migrations, respectively (Figures 16 and 17).

In 1987 and 1988, surveys were conducted from a single-engine, fixed-wing Stinson L-5 Super Cub equipped with LORAN-C and a radar altimeter in addition to the usual suite of communication and navigation equipment (Appendix A). Survey airspeed was 90 kn (167 km/hr) and altitude varied from 1,000 ft (305 m) to 750 ft (229 m) ASL, depending upon sea state, sun glare, and visibility. Regardless of the altitude flown, any gray whale present within a swath 0.5 nm (0.9 km) wide on each side of the aircraft was probably observed. When whales were seen beyond that distance, the aircraft was diverted to confirm the species, numbers, and direction of movement.

DATA COLLECTION

Data were recorded on a tape recorder via the pilot/observer's headset microphone. LORAN-C fixes were transferred electronically as "way-points" and were down-loaded at the termination of each flight. All species of cetaceans, large pinniped groups, feeding aggregations of birds, as well as gray whales were recorded, whether they were in or adjacent to the study area. Sighting data included species, numbers, location (latitude and longitude from LORAN), direction of movement, and sea state. Sea surface temperatures were recorded for most sightings, although the PRT-5 remote radiometer was not always available.

DATA ANALYSIS

Course Headings

The mean direction of movement was determined using circular statistics (Batschelet 1981) since orientation relates to a circle in which headings cannot exceed 360°. The average heading (ϕ) was defined as:

$$\phi = \begin{array}{ll} \arctan x / x \text{ for } x > 0 & \text{(or)} \\ 180^\circ + \arctan y / x \text{ for } x < 0 & \end{array}$$

where $x = 1/n\ (\cos\phi + \cos\phi_1 + \cos\phi_2) + \ldots \cos\phi_n)$

$y = 1/n\ (\sin\phi + \sin\phi_1 + \sin\phi_2) + \ldots \sin\phi_n)$

The angular deviation (i.e. standard deviation of linear statistics) was defined as

$$s\ (\text{degrees}) = 180^\circ/\pi\ [2(1 - r)]^{1/2}$$

where r = mean vector length

$$r = 1/n\ [(\Sigma \cos\phi_i)^2 + (\Sigma \sin\phi_i)^2]$$

Distribution and Abundance

Distances from shore were determined by overlaying a mylar map of the coastline on a plot of all pod sightings and measuring from each sighting to the shoreline. These data were used to construct frequency histograms of numbers of pods and individuals by distances from shore. The frequency of pod occurrences and whale abundances were also plotted within distance intervals, i.e. visual study blocks. From these data, the number of pods/km² and gray whale density/km² by block and for the entire study area were calculated.

Using an overlay, the water depth at each sighting was estimated. The frequency of pod occurrences and abundances were calculated within seven water depth intervals: 10 to 30 m; 30 to 60 m; 60 to 100 m; 100 to 200 m; 200 to 300 m; 300 to 400 m; and 400+ m.

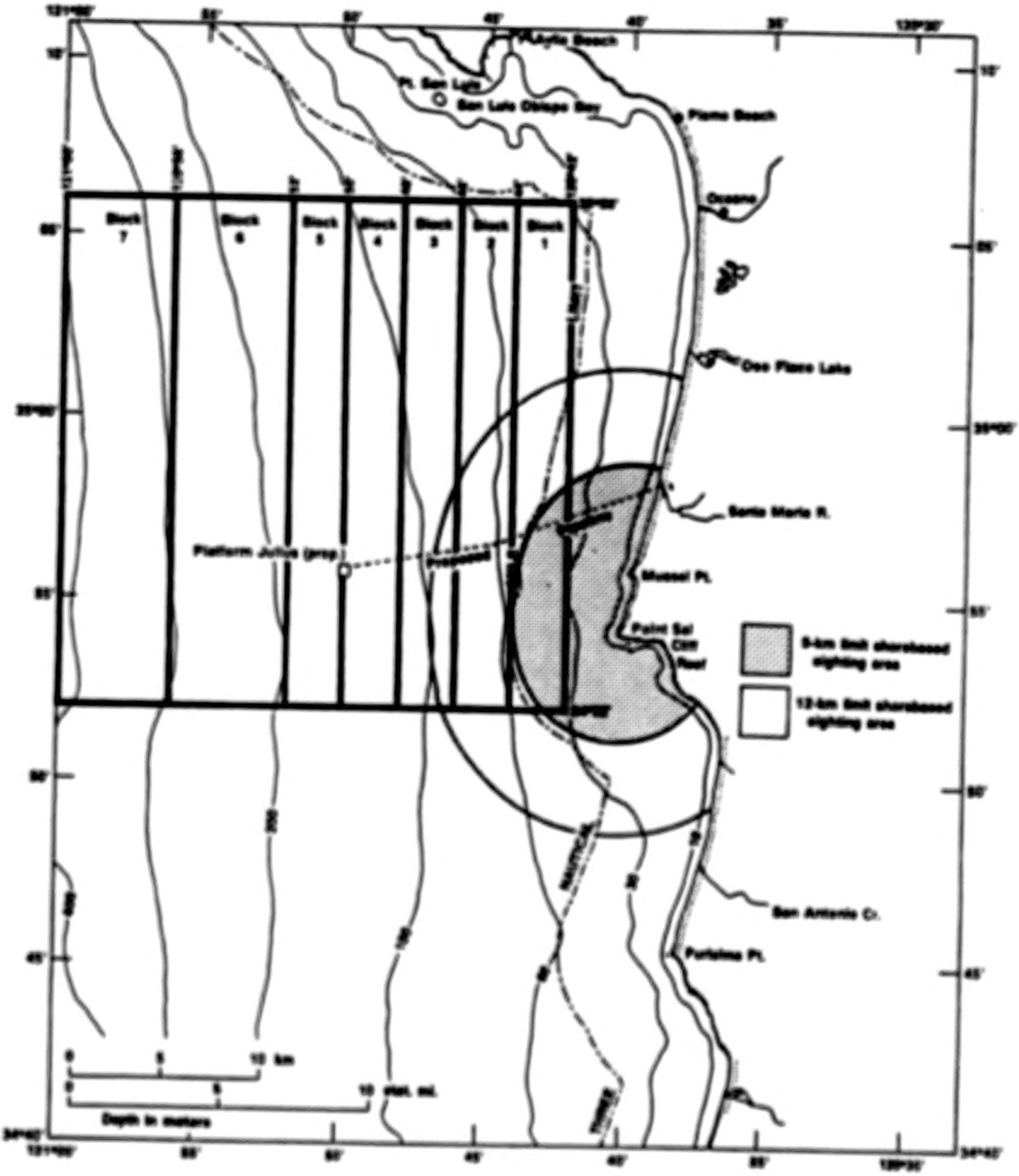

Figure 15. Location of aerial transect lines off Point Sal during southbound migration in January 1987. Concentric ellipses represent the 5- and 12-km sighting limits from shorebased survey sites.

Using an overlay, the water depth at each sighting was estimated. The frequency of pod occurrences and abundances were calculated within seven water depth intervals: 10 to 30 m; 30 to 60 m; 60 to 100 m; 100 to 200 m; 200 to 300 m; 300 to 400 m; and 400+ m.

SHOREBASED SURVEYS

Dates of field surveys and the types of data collected by shorebased observers are presented in Table 3. Ten field surveys were conducted between April 1986 and April 1988. In January 1987 field surveys were conducted during the southbound gray whale migration; all other field surveys were of the northbound migration.

Shorebased studies during the January 1987 southbound migration were conducted from Point Sal between 0830 and 1500 hrs (PDST). The success of any survey period was highly dependent on weather conditions. High winds limited the ability to detect whales and prevented extended observation periods; activities in these conditions were usually terminated by early afternoon.

In April/May 1986, Phase B surveys were conducted between approximately 0700 and 1715 hrs (PDST), although the observation time varied from day to day. Conditions during the survey were generally fair, although high winds prevented observations of the coast north of Point Sal. Other surveys during the northbound migration between March 1987 and April 1988 were conducted between 0630 and 1800 hrs, although the amount of survey time again varied from day to day, depending on weather and sea state.

OBSERVATION SITES

Initially, all observations were made from two or three sites within 20 m of a USGS benchmark atop Point Sal. However, under most conditions it was not possible to see whales north of Mussel Point; thus an additional site was established at Mussel Point (Figure 15). The Point Sal site allowed observers to track animals approaching from the south whereas observations from Mussel Point allowed tracking of northbound animals past the Santa Maria River in the vicinity of the proposed pipeline.

The Point Sal observation site was located at 34°54.21'N latitude, 120°40.02'W longitude at a height of 117 m above mean sea level (MSL). The site overlooks the coastline from Point San Luis to Purisima Point. Mussel Point and the Santa Maria River are 2.9 km and 4.8 km north, respectively; Point San Luis is 29 km to the northwest; and Pismo Beach is 25.7 km north of the study site (Figure 15).

The Mussel Point observation site is located at a 34°55.79'N latitude, 120°39.83'W longitude at a height of 67.1 m (MSL). This site provided observers with a uninterrupted view of the nearshore area between Point Sal and the Santa Maria River, in the vicinity of the proposed pipeline route to shore (Figure 15).

Landmarks used during the study (some previously named and others with names coined by the field team) included: Reef, Cliff, Point Sal State Beach, Lion Rock (all east or southeast of Point Sal); Point Sal, Point Sal Reef, Mussel Point, and the Santa Maria River (Figure 15). Lion Rock is an important seabird roosting habitat and sea lion (*Zalophus californianus*) haul-out just south of Point Sal.

Land access to the study sites was through private property over roads which required four-wheel drive vehicles. During and after rains these roads were subject to closure by the landowners, which limited some periods of observation. During a closure in March 1987, the field team was airlifted to Point Sal by Aspen Helicopters, through the courtesy of the MMS Santa Maria office.

OBSERVATION TEAMS

Shorebased studies were conducted by one or two teams of two or three individuals each: first observer, second observer, and data recorder. The first observer's primary and secondary responsibilities were theodolite tracking of whales and observation of whale behavior. The second observer located in-coming pods, observed whale behavior, and functioned as a backup theodolite operator. Observers utilized binoculars (7x35; 7x50; 8x40) to locate whales and observe their behavior. The data recorder was

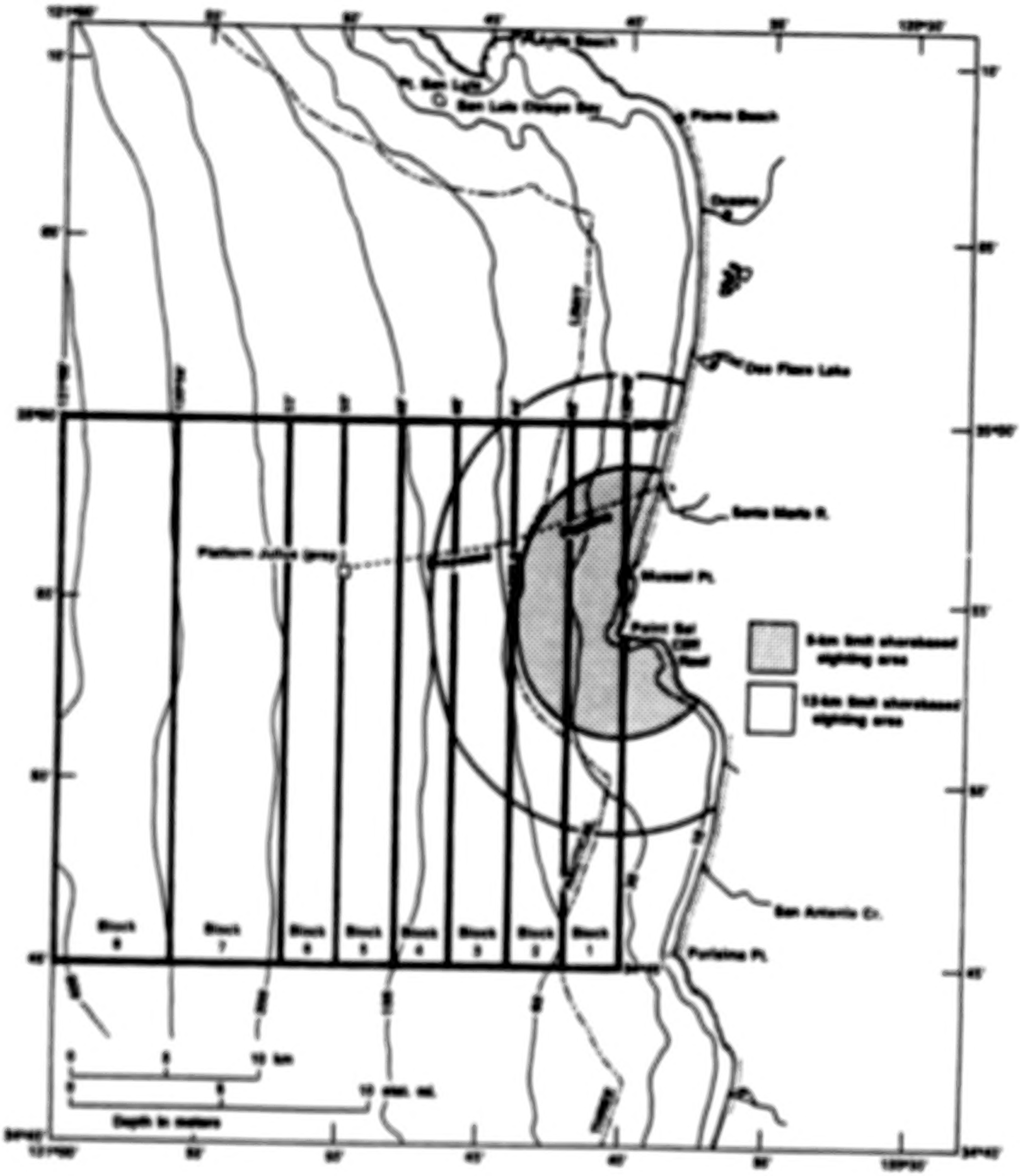

Figure 17. Location of aerial transect lines off Point Sal during northbound migrations in 1987 and 1988. Concentric ellipses represent the 5- and 12-km sighting limits from shorebased sites.

TRACKING PROCEDURES

The observer(s) scanned the study area with binoculars and when a gray whale individual or pod was sighted (usually by a blow), it was assigned a specific number, sequential on each separate day. The initial theodolite fix was usually made at the next surfacing when the number of individuals in the pod was also estimated. The pod's position and any behavior were recorded with each subsequent observation (surfacing); estimates of the numbers of whales in a pod were refined with additional sightings. When making theodolite fixes, the observer positioned the crosshairs as close to the blow hole as possible or on the forward one-third of the dorsum. In some cases where the front region was not visible, sightings were taken on the flukes when a dive was initiated or on the "footprint" caused by turbulence from the flukes.

Theodolite Accuracy

The theodolite positions an object based on its vertical (declination) and horizontal (azimuth) angles from the observation site. This method has proven successful in observing gray whale movements in studies by Malme *et al.* (1984), Sumich (1983), and Braham (1977). Different theodolite models were used in the present study, each with slightly different characteristics (Table 4). All models were equipped with 30x eyepieces. The estimated field of view for all models ranged from 28 m at 1 km to 111 m at 4 km (Appendix B).

Table 4. Specifications of theodolites used during the gray whale monitoring surveys.

Model/Readout	Least Count	Precision	Surveys
Wild T-16/ Vernier Scale	30 sec	15 sec	1,2
Leitz SET4/LCD	5 sec	5 sec	3
Zeiss ETH3/LCD	1 sec	2 sec	3,4
Leitz DT20E	20 sec	10 sec	5,6

1 = April/May 1986 2 = January 1987
3 = March 1987 4 = May 1987
5 = March 1988 6 = April 1988

An error analysis was performed to determine the accuracy of whale positions and the error induced by increasing offshore distances using the three different models and the elevations where they were used. The analyses are presented in Appendix B.

Sources of Observer Error

The ability to accurately "shoot" the position of migrating whales is a function of the limits of the instruments, weather conditions, and of the observers' experience and fatigue. Therefore, each observer practiced and performed calibration checks prior to going into the field and standardized techniques with the other observers. On site, each theodolite was zeroed and leveled prior to use and these were checked on a regular basis during the day to correct any drift due to the wind or settling of the tripod.

New members of the field team were checked out on the equipment by individuals with previous theodolite experience and they practiced tracking whales prior to recording data. Field teams always included at least one and usually two individuals with prior experience. Mr. Michael Poole (University of California at Santa Cruz) participated in all surveys to provide quality assurance/quality control and his interpretation of behaviors.

Recent studies have indicated that the experience of the theodolite operator is secondary to weather conditions and sea state as a source of error (Tyack 1986, Malme *et al.* 1984, Malme *et al.* 1983b, Brelwick and Dahlheim, unpubl. ms.). The ability to accurately track whales and observe their behavior decreases as their distance from the observer increases. Therefore, daily surveys were usually terminated when conditions reached Beaufort sea state 4 (winds of 10 to 15 kn and numerous white caps). Other conditions, such as fog, haze, and glare were also taken into account when deciding if tracking of a particular pod or daily observations in general should be terminated.

Team members were rotated among first observer, second observer (when present), and data recorder to minimize fatigue. Rotation took place every two to three hours, depending on the number in the team.

The theodolite operator was responsible for determining when tracking of a particular pod was to begin. Sightings at the extreme limit of the instruments' capabilities and the observer's ability were regarded as "approximate" and were not analyzed if there was an obvious discrepancy between consecutive readings or if the actual blow was missed and the observer targeted the whale's "footprint". Approximate data were not analyzed if the distance traveled, the dive times, or the swimming speeds were erratic. Tracking of a particular pod could be terminated for one of several reasons: 1) sighting conditions were not adequate due to glare or other factors, 2) another pod was entering the field of view, 3) long periods of milling behavior (see definition Table 3) which might result in the loss of information on other pods, and 4) the animals were traveling out of the range for accurate tracking.

Common or recurring problems in the field included: 1) defining pods when joining and splitting occurred; 2) re-sighting the lead individual each time, especially if the pod milled or engaged in behavior other than traveling; 3) losing sight of the animals due to glare, fog, or the coastal configuration; and 4) recording the numbers of blows in multiple-individual pods.

DATA ANALYSIS

Following each field survey, the field team assembled to check data sheets for obvious errors or omissions. Corrections were made on the basis of field notes, daily field logs, and the observers' recollection of events. Shorebased data were reduced according to pod size and survey within each migration phase: Southbound (non-cow/calves and cow/calves); northbound Phase A (non-cow/calves) and Phase B (cow/calves).

Field data were entered into Lotus 1-2-3 spreadsheets on IBM PC-compatible hardware; backup copies of the data files were archived on floppy disks. The raw data printout included: observation site (Point Sal or Mussel Point), date, pod number, time, observer, azimuth, declination, behavioral codes, weather and sea state, correction for magnetic heading, and the offset (vertical and horizontal) of the theodolite from the USGS reference benchmark. From these data, swimming speeds, distances traveled between sightings, and polar X-Y coordinates were calculated using an MBC-developed computer program called "Track".

The coastline of the study area was digitized from USGS maps using a Numonics Model 2210 Digitizing Tablet and Jandel Scientific Corporation Sigma-Plot Software. The polar coordinates for each observation were converted to rectangular X-Y coordinates, transferred to plotting programs, then computer plotted on the coastline map with a Hewlett-Packard 7475A Plotter and Jandel Scientific Corporation Sigma-Scan software.

Course Headings

The heading (in °True North) was calculated between consecutive sightings. The mean direction of movement for each pod over its track length was calculated using circular statistics.

Distribution

Data obtained during the track analysis were used to determine how far the whales were offshore. Because of the varying coastal configuration, distances from shore were calculated by two methods.

Technique I. Distances from shore were calculated by overlaying a mylar map of the coastline on the computer generated tracks, and measuring each pod's distance from the closest point on shore. Multiple sightings along a single track were averaged by taking values at the beginning, midpoint and endpoint of each track. The resulting average represented the distance of that particular pod from shore. The distances of pods from shore were also converted to frequencies within specified intervals, and graphed by pod size. Bias in this technique results from the fact that the coastline is not straight, tracks were not of the same duration, and the whales' direction of movement was not parallel to the coast.

Technique II, Transect Analysis. The individual tracks of pods were also plotted to determine how far they were offshore as they passed "fixed" (largely east-west) transect lines between the southern ("Reef") and the northern (Santa Maria River) limits of the study area. The mean distance offshore was calculated on the basis of all pods which passed that particular transect line. These mean distances were then presented graphically by migration phase to illustrate the inner portion of the gray whale migration route in this study area.

Swimming Speed

It was often difficult to take repeated theodolite readings on the same individual in a pod of several animals, especially if sighting conditions were marginal or animals were at the extreme edge of the effective viewing area. Consequently, it was necessary to standardize data to account for potential error in sightings of more than one individual within a pod. The criteria used by Malme *et al.* (1983b) was used to determine acceptable maximum rates of travel for pods consisting of one to four animals. These limits are:

Group Size	Maximum Acceptable Speed
1	18 km/hr
2	24 km/hr
3	30 km/hr
4	36 km/hr

These maximum speed limits assume worst case conditions of 100 m error between two sightings and that any two individuals within a group could be separated by as much as 100 m, i.e. 3 to 4 body lengths.

The "interval" swimming speed along a particular whale track was defined as the distance between two consecutive theodolite readings divided by the difference in the two times associated with the readings. Swimming speed over the entire track was calculated (i.e. averaged) by summing the individual interval speeds over the entire track and dividing by the total number of intervals.

Dive Duration

The duration of "interval" dives was defined as the time interval between two consecutive theodolite sightings during which the whale was underwater. Track or pod dive times were calculated by summing the interval dive times measured over the entire track and dividing by the number of intervals.

Dive durations were calculated in three ways. An overall average dive time was calculated, regardless of the fact that gray whales generally precede a long dive with several dives of shorter duration. The frequency of dives in 0.5 min intervals was calculated to establish the ratio of long to short dives and to determine the average duration of both short and long dives.

In order to compare the present findings with those of previous studies, the durations of dives were grouped according to the methods of previous investigators (Sumich 1983, Swartz *et al.* 1986, Jones and Swartz 1987b). All dives up to 1.0 min in duration were considered as "short" dives; "long" dives were considered to be 1.0 to 10 min in duration. Dives longer than 10 min were excluded from the analyses because they were considered non-sequential data (i.e. a series of short dives was missed) or not representative of normal diving patterns during migration.

Respiration Rates

The rate at which migrating gray whales breathe under various conditions may provide an index by which stress induced by the construction or operation of a platform can be measured. However, it is a difficult parameter to quantify. Malme *et al.* (1983c) determined that respiration times could be reliably collected within 2 km of shore if observers concentrated on only one pod. Blow interval data for cows appeared to be reliable, but blow data for calves were subject to greater error because of their size and position relative to the cow. Inaccurate respiration times were usually due to missed blows or misidentifying the individual responsible. The most accurate respiration rate calculated was based on the total number of blows from the entire group. This respiration rate was defined as the number of blows per hour. It is calculated as:

$$\frac{\text{Total Number of Observed Blows}}{\text{Number of Whales in the Pod}} \cdot \begin{array}{l}\text{Total Track Time Between}\\ \text{First and Last Blow}\end{array}$$

During the 1986 northbound Phase B survey, respiration rates were only determined for cows and only for animals within 1.0 km of shore. In January, rates were determined for all pods within 2 km of shore in order to look for differences as a function of distance from shore.

Behavioral Observations

Behaviors other than swimming speed, dive duration and respiration rates were tabulated within four different categories: traveling behavior (traveling or milling); surfacing characteristics (blow, blow mother, blow calf, blow both, surface without blow observed); surface-active and social behaviors; and dive attitude (flukes observed or not observed). The frequency of each type of behavior within each category was tabulated, summarized for each survey, and expressed as both a percent of the total number of behaviors within each particular behavior category, and as a total of all observed behaviors.

The term "calf" refers to the smaller individuals in pairs (or triads) which are one half or less the length of the accompanying whale and estimated to be less than 6 m long. The term "mother-young" was used by the project's aerial observer. For consistency, these two terms are considered synonymous and presented as "cow/calf" in the text.

Vessels and aircraft in the study area were noted and their movements tracked. Vessels were monitored when whales were nearby to determine if and how the whales responded. All tracking data were sorted to identify instances when whales and vessels were present simultaneously. The tracks of the whales and the vessels were then plotted together and scrutinized to determine if avoidance or attraction took place.

STATISTICAL ANALYSIS

The mean and standard deviation of each parameter was determined and summarized by survey, year, pod size, and migration phase. Data sets included: abundance, distribution, direction of movement, swimming speed, dive time, and respiration rate.

Data sets were statistically analyzed using parametric statistics (Sokal and Rohlf 1969) after it was determined that frequency of distributions of all parameters approached normal distributions. Regression analysis (Lotus 1-2-3 subroutines) were used to test relationships between various parameters. In addition, Student's T test was used to test the null hypothesis that single gray whale distribution and behaviors were not significantly different than gray whales traveling in multi-individual pods. This hypothesis was tested to determine if future comparative studies could rely on data collected on singles (less likely to be biased by sighting error). Both null hypotheses were accepted at a probability greater than or equal to p=0.05 , two tailed test).

The level of detectability "d" (the degree at which a change can be detected from the mean value with a 95% probability) of each parameter was determined, based on the baseline sample sizes of southbound, northbound Phase A, and northbound Phase B data. Data for each phase were pooled over surveys for this analysis. The equation for this formula was supplied by Douglas Chapman (NMFS, pers. comm.) and is described as:

$$d^2 \geq (1.96 + 1.64)^2\ S^2\ (1/n_1 + 1/n_2) \text{ according to Chapman (unpubl. ms.)}$$

where d = difference that can be detected from the baseline sample at P=0.95

s^2 = baseline sample variance

n_1 = sample size for baseline data

n_b = sample size for treatment (operational) data
1.96 = normal probability for 2-tail sample test at P=0.05
1.64 = normal probability for 1-tail sample test at P=0.05

Throughout this report, the data are presented in metric units. For the reader's convenience, metric to English conversion tables are presented in Appendix C.

RESULTS

AERIAL SURVEYS OF THE SOUTHBOUND MIGRATION

Data and frequency-distribution graphics of the aerial survey of gray whales are presented in Appendices D-1 through D-18.

WEATHER AND SEA STATE

Surveys of the southbound migration were flown on the morning of 21 January, the morning and afternoon of 22 January, and from mid-morning to early afternoon on 23 January 1987. Weather and sea state varied from day to day, ranging from calm seas to Beaufort 1 to 3 and scattered whitecaps. Survey time totaled 11.4 hrs (2.9 hrs/survey).

Table 5. Composition of the southbound gray whale migration, by pod size and numbers of whales, aerial observations, January 1987.

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
1	5	16.1	5	5.0
2	5	16.1	10	9.9
3	5	16.1	15	14.9
4	3	9.7	12	11.9
5	5	16.1	25	24.8
6	1	3.2	6	5.9
7	1	3.2	7	6.9
8	1	3.2	8	7.9
Non-Cow/Calves*	26	83.9	88	87.1
Cow/Calves (Pairs)	3	9.7	6	5.9
2 Adults/1 Calf	1	3.2	3	3.0
Double Cow/Calves	1	3.2	4	4.0
Survey Total	31	100.0	101	100.0

* 1 extralimital not included in database

ABUNDANCE

Thirty-one pods and 101 gray whales were observed during aerial surveys of the southbound migration between 21-23 January 1987 (Table 5). These included 26 non-cow/calf pods and 5 cow/calf pods. The mean pod size was 2.6 whales/pod and they crossed the study area at a rate of 8.6 whales/hr. Most whales (95%) traveled in groups of two or more.

The overall mean density of gray whales in the study area was 0.031 whales/km^2; the greatest density was in Block 4, 14.8 to 18.5 km offshore. Twenty-five non-cow/calf pods (86 whales) averaged 0.027 whales/km^2, ranging from 0.005 to 0.055 whales/km^2 by block (Appendix D-19). The mean density of non-cow/calf pods was 0.007/km^2, with densities ranging from 0.001 to 0.018 pods/km^2 by block. Cow/calf pods had an average densities of 0.004 whales and 0.001 pods/10 km^2 for the entire study area (Appendix D-20).

MIGRATION CORRIDORS

The numbers of non-cow/calf pods and whales in Blocks 1 through 7 approximated a normal distribution (Table 6), ranging from zero in Blocks 1 and 6 to seven in Block 4. The peak number of whales (22) was in Block 4, 12.8 to 16.0 km from shore.

Southbound gray whales in the study area were an average of 17.4 km from shore, ranging from 4.5 km to 31.5 km (Figure 18). In general, larger pods occurred further offshore (Table 7 and Appendix D-21). One (extralimital) pod was 0.5 km offshore near the Santa Maria River.

Table 6. Distribution of southbound gray whales, by distance from shore and water depth and for cow/calf pairs and non-cow/calf pairs, aerial observations, January 1987.

		Pods			Whales			
	Intervals	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
				Non-Cow/Calves				
Block	(km)							
1	3.2- 6.4	1	4.0	4.0	5	5.8	5.8	5.0
2	6.4- 9.6	3	12.0	16.0	6	7.0	12.8	2.0
3	9.6-12.8	4	16.0	32.0	12	14.0	26.7	3.0
4	12.8-16.0	7	28.0	60.0	22	25.6	52.3	3.1
5	16.0-19.2	4	16.0	76.0	18	20.9	73.3	4.5
6	19.2-28.6	5	20.0	96.0	19	22.1	95.3	3.8
7	28.6-32.0	1	4.0	100.0	4	4.7	100.0	4.0
Total		25	100.0		86	100.0		3.4
Depth	(m)							
A	10-30	0	0.0	0.0	0	0.0	0.0	0.0
B	30-60	1	4.0	4.0	5	5.8	5.8	5.0
C	60-100	6	24.0	28.0	15	17.4	23.3	2.5
D	100-200	15	60.0	88.0	53	61.6	84.9	3.5
E	200-300	2	8.0	96.0	9	10.5	95.3	4.5
F	300-400	0	0.0	96.0	0	0.0	95.3	0.0
G	400+	1	4.0	100.0	4	4.7	100.0	4.0
Total		25	100.0		86	100.0		3.4
				Cow/Calves				
Block	(km)							
1	3.2- 6.4	1	20.0	20.0	2	15.4	15.4	2.0
2	6.4- 9.6	0	0.0	20.0	0	0.0	15.4	0.0
3	9.6-12.8	1	20.0	40.0	2	15.4	30.8	2.0
4	12.8-16.0	1	20.0	60.0	3	23.1	53.8	3.0
5	16.0-19.2	0	0.0	60.0	0	0.0	53.8	0.0
6	19.2-28.6	1	20.0	80.0	4	30.8	84.6	4.0
7	28.6-32.0	1	20.0	100.0	2	15.4	100.0	2.0
Total		5	100.0		13	100.0		2.6
Depth	(m)							
A	10-30	0	0.0	0.0	0	0.0	0.0	0.0
B	30-60	1	20.0	20.0	2	15.4	15.4	2.0
C	60-100	1	20.0	40.0	2	15.4	30.8	2.0
D	100-200	1	20.0	60.0	3	23.1	53.8	3.0
E	200-300	1	20.0	80.0	4	30.8	84.6	4.0
F	300-400	1	20.0	100.0	2	15.4	100.0	2.0
G	400+	0	0.0	100.0	0	0.0	100.0	0.0
Total		5	100.0		13	100.0		2.6

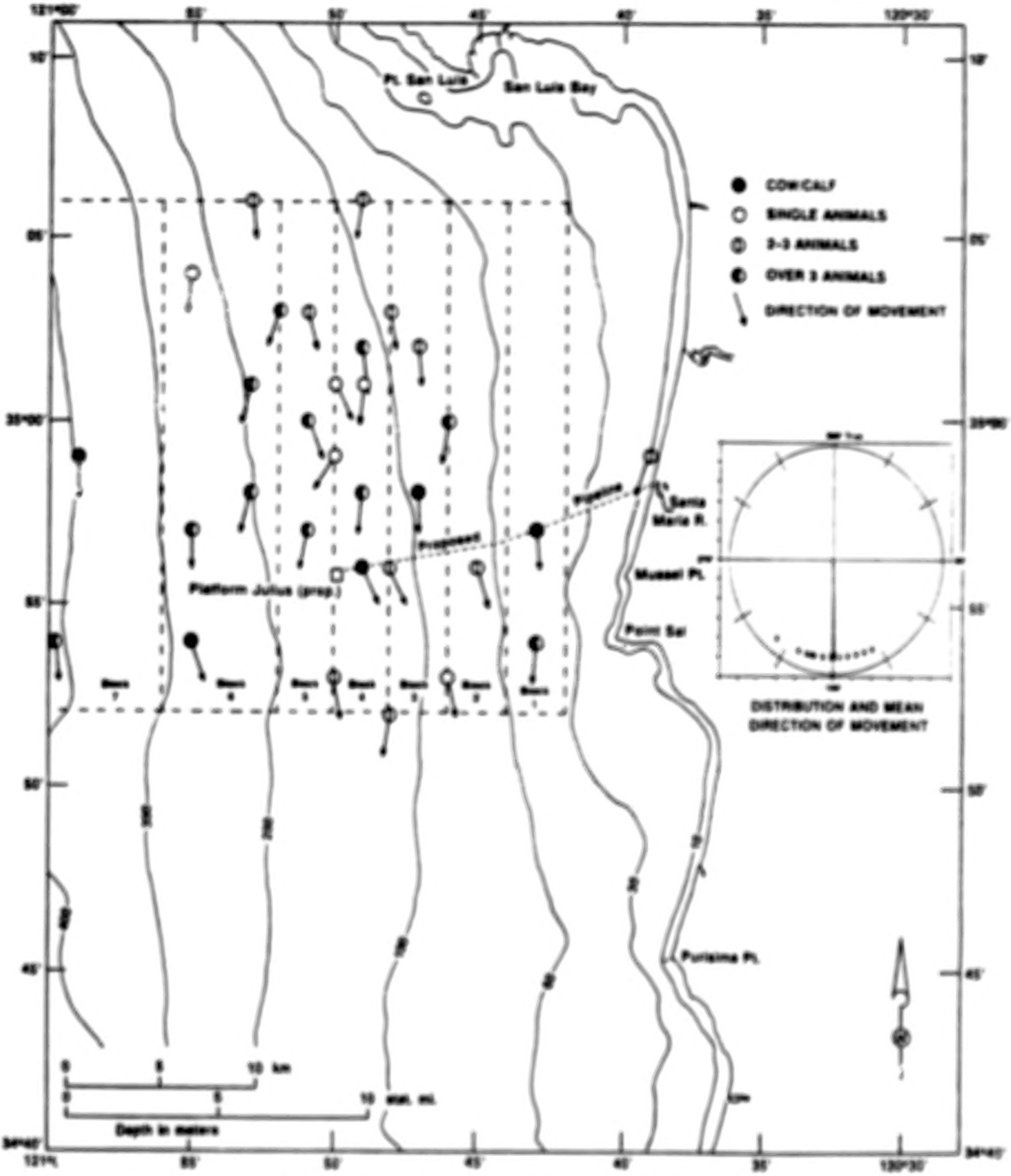

Figure 18. Locations and headings of gray whale pods, aerial observations, January 1987.

The 25 non-cow/calf pods observed were an average of 17.4 km offshore, and most abundant between 12 and 24 km (Appendix D-22). The five cow/calf pods were observed between 4.5 and 31.2 km from shore with a mean distance of 17.2 km.

Non-cow/calf pods tended to travel over water depths of 100 and 200 m. Sixty percent of the pods and 62% of the whales were in this zone (Table 6).

Table 7. Offshore distribution of southbound gray whales, by pod size, aerial observations, January 1987.

		Distance from Shore (km)
Pod Size	No. of Pods	Mean ± S.D.
1	5	17.7 ± 3.9
2	4	14.6 ± 5.2
3	5	16.6 ± 4.9
4	3	23.8 ± 6.8
5	5	14.2 ± 6.6
6	1	22.5
7	1	17.0
8	1	23.5
Non-Cow/Calves	25	17.4 ± 6.1
Cow/Calves	5	17.2 ± 9.9
Survey Total	30	17.4 ± 6.6

Table 8. Headings of southbound gray whales by pod size and numbers of individuals, aerial observations, January 1987.

			Heading (Angle °True North)
Pod Size	No. of Pods	No. of Whales	Mean ± S.D.
1	5	5	189.9 ± 19.6
2	4	8	169.8 ± 0.0
3	5	15	177.0 ± 14.0
4	3	12	177.6 ± 14.0
5	5	25	191.4 ± 0.0
6	1	6	196.0 -
7	1	7	176.0 -
8	1	8	186.0 -
Non-Cow/Calves	25	86	181.2 ± 26.4
Cow/Calves	5	13	171.0 ± 11.5
Survey Total	30	99	179.2 ± 26.4

DIRECTION OF MOVEMENT

The mean heading of the 30 gray whale pods observed in January was nearly due south (mean of 179.2° True; Table 8). Pod ranged from 156° to 215° True, nearly equal numbers of whales traveling on either side of the mean heading (Appendix D-23). The mean heading of the five cow/calf pods (mean of 171° True) was more easterly than non-cow/calves (mean of 181° True).

SHOREBASED SURVEYS OF THE SOUTHBOUND MIGRATION

Weather and sea state, gray whale survey data, frequency distribution graphics by parameters, and vessel and aircraft sightings are presented in Appendix E-1 through E-20.

WEATHER AND SEA STATE

Shorebased surveys of southbound gray whales were conducted between 12 and 21 January 1987. The field survey on 12 January was cancelled midday because of inclement weather. Following a week of poor weather, field teams returned on 17 January. Between 17 and 21 January the weather was cold and generally clear or hazy with light to moderate winds in both morning and afternoon. Sea state varied from Beaufort 1 to 2 in the morning and Beaufort 2 to 3+ in the afternoon. Glare from the sun's reflection on the water usually became a problem in the early to mid afternoon and occluded portions of the viewing area. Field time totaled 31.2 hrs of observations and averaged 5.2 hrs/day, but due to viewing and weather conditions, varied from 1.4 to 8.3 hrs/day.

ABUNDANCE

From 12 to 21 January 1987, 70 pods and 131 individual gray whales were monitored between Point Sal and Mussel Point (Table 9). These included 67 non-cow/calf pods (125 individuals) and 3 cow/calf pairs (3 cows and 3 calves). The average pod-size was 1.9 whales; means of 2.2 pods and 4.2 individuals were observed per hour in the study area. Most whales traveled in pods of two or more individuals. The 99 whales in multi-whale pods accounted for 76% of the total observed.

MIGRATION CORRIDORS

On average, the 54 pods of southbound gray whales which were tracked were 3.8 km from shore (Table 10), but were observed as close as 100 m and as far as 10.1 km from shore. The 51 pods of non-cow/calves occurred at an average of 4.0 km from shore, whereas the three cow/calf pairs were at a mean of only 1.8 km from shore (Table 10).

Gray whales were first observed as they approached Mussel Point, moving south-southeast across San Luis Bay (Figure 19). Most whales entered the study area from offshore waters, 7.7 to 8.6 km off the Santa Maria River, where water depths are greater than 60 m. Between Mussel Point and Point Sal, they followed the coastline, between 3.3 and 4.0 km from shore and in water depths of 30 to 60 m. As they passed Point Sal, some whales headed offshore while others moved inshore to just off the tip of Point Sal where water depth varied between 6 and 10 m.

Table 9. Composition of the southbound gray whale migration, by pod size and numbers of individuals, shorebased observation, January 1987.

Pod Size	No. of Pods	% of Total	No. of Indiv.	% of Total
1	32	45.7	32	24.4
2	18	25.7	36	27.5
3	14	20.0	42	32.1
4	1	1.4	4	3.1
5	1	1.4	5	3.8
6	1	1.4	6	4.6
Cow/Calves	3	4.3	6	4.6
Total	70	100.0	131	100.0

Table 10. Composition of the southbound gray whale migration, by pod size and numbers of individuals, shorebased observation, January 1987.

Pod Size	No. of Pods	% of Total	No. of Indiv.	% of Total
1	32	45.7	32	24.4
2	18	25.7	36	27.5
3	14	20.0	42	32.1
4	1	1.4	4	3.1
5	1	1.4	5	3.8
6	1	1.4	6	4.6
Cow/Calves	3	4.3	6	4.6
Total	70	100.0	131	100.0

Overall pod size was significantly correlated with distance from shore ($r=0.386$, $df=49$, $p<0.01$). Single individuals and pairs traveled at mean distances offshore of 3.4 and 3.2 km, respectively (Table 11). Triads occurred at an average distance of 5.2 km from shore, while pods of four and more individuals occurred still farther offshore (Appendix E-21).

The three cow/calf pairs tracked were at a mean of 1.8 km from shore. Two pods traveled along the 30 m isobath while the other was very close to shore (within the 10 m isobath) and followed the coastline around Point Sal (Appendix E-22). Although all calves were small, the latter appeared to be extremely young, judging from its dark body pigmentation, indentations associated with hair follicles, and poorly coordinated breathing and diving rhythm.

DIRECTION OF MOVEMENT

The results of tracking analysis for January 1987 (Appendix E-23) indicate that whales headed southeast through the study area, with an average heading of 160° True (Table 12). Pod headings were generally similar, with 34 of 54 pods (63%) traveling between 150° and 180° True (Appendix E-24). Whales close to shore tended to follow the shoreline and therefore the headings were more variable than those offshore.

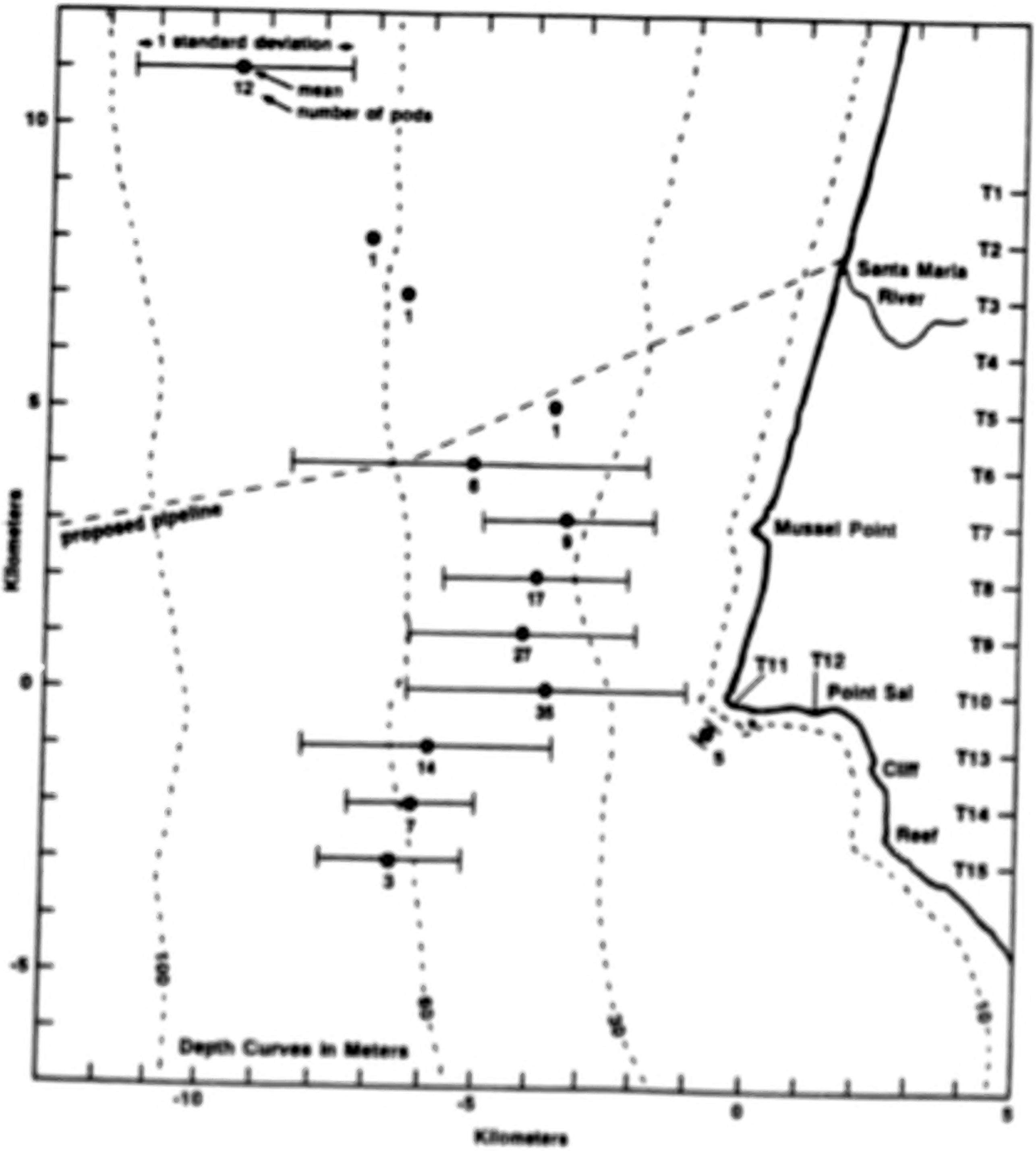

Figure 15. Mean migration corridor of southbound gray whale pods in relation to the coast and bathymetry, shorebased observations, January 1987.

The 51 non-cow/calf pods swam at an average heading of 162° True, ranging from 138° True for a pod of five individuals to 162° True for pods of two individuals (Table 12). The three cow/calf pairs had a more easterly mean heading of 131° True, although this group showed a similar range of variability as that of the non-cow/calf pods.

SWIMMING SPEED

The 41 gray whale pods for which swimming speeds were determined traveled at an average speed of 7.1 km/hr (Table 13). Overall, swimming speeds approached a normal distribution, with most (31 individuals or 73%) between 4 and 9 km/hr. Non-cow/calf pods averaged 7.2 km/hr, almost 2 km/hr faster than the average speed (5.0 km/hr) of cow/calf pairs. The mean speeds of the various-sized pods were quite similar, ranging from 7.3 km/hr for singles to 7.8 km/hr for pods of three individuals. One pod of five had a mean speed of 11.4 km/hr (Table 13).

DIVE DURATION

The mean duration of 593 dives by 46 pods of southbound whales was 2.4 min (Table 14; Appendix E-25). Dives were about equally divided between short (less than 1 min) and long (1 to 10 min) dives; 292 dives (49%) were short and 301 (51%) long. The mean duration of short dives (observed in 41 pods) was 0.5 min and of long dives (observed in 46 pods) 4.0 min.

Non-cow/calf pods and cow/calf pairs exhibited the same average short dive durations (0.5 min); however, long dive durations differed, the 3 cow/calf pairs averaging 3.2 min and 43 non-cow/calf pods averaging 4.0 min (Table 14).

Dive durations of non-cow/calves were negatively correlated with pod size ($r=0.522$, $df=41$, $p<0.01$). Dive times ranged from 3.1 min for 19 singles to 1.0 min for a single pod of 4 whales. Additionally, the long dives of singles (4.6 min) were significantly longer ($F_{16,24} = 2.146$, $P<0.05$) than the long dives of whales traveling in groups (3.6 min). The dive patterns of 5 single whales included regular long dives as well as short, clumped dives (Appendix E-26).

RESPIRATION RATES

The respiration rates of 43 southbound whales averaged 21.1 blows/hr (Table 15). However, the average respiration rate of non-cow/calf pods was 2.9 blow/hr higher than that of the mothers of cow/calf pairs. A similar level of variation was observed among non-cow/calf pods of varying pod sizes. The breathing rates of most whales (35 of 43, 81%) were between 10 and 30 blows/hr, with the mode occurring between 20 and 25 blows/hr. Mean respiration rates and mean dive durations were inversely correlated ($r=0.386$, $df=41$, $p<0.05$), respiration rates decreasing as dive durations increased (Appendix E-27).

BEHAVIOR

Southbound migrants displayed little milling, social interactions, or active surface behavior (Table 16). Milling did occur on two occasions, in a pod of two whales 0.1 km off Point Sal and in a pod of two individuals approaching Mussel Point. Most observations were of whales in a normal exhaling attitude, the remainder were of other exposed body parts and blows were not observed. A few sightings were made of only the "footprints" left on the water surface as whales dove.

Twenty of 737 observations (3%) involved social or surface-active behavior. Fourteen breaches and three rolls, with pectorals visible, were the only active surface behaviors seen (Table 16). Nine of the breaches were made by single traveling animals and five were made by whales in pods. Most breaching activity occurred in the distant portion of the viewing area, at an average of 6.3 km from shore and ranging from 2.9 km (a double breach by a pod of two whales) to 8.6 km (one breach by a single animal) from Point Sal. Breaching occurred between 1100 and 1400 hrs.

Table 11. Frequency of observation by distance of southbound gray whales, shorebased observations, January 1987.

	Pods			Whales			
	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Distance (km)							
0-1	13	24.1	24.1	21	20.8	20.8	1.6
1-2	4	7.4	31.5	8	7.9	28.7	2.0
2-3	7	13.0	44.4	12	11.9	40.6	1.7
3-4	5	9.3	53.7	7	6.9	47.5	1.4
4-5	7	13.0	66.7	10	9.9	57.4	1.4
5-6	9	16.7	83.3	21	20.8	78.2	2.3
6-7	2	3.7	87.0	5	5.0	83.2	2.5
7-8	3	5.6	92.6	5	5.0	88.1	1.7
8-9	1	1.9	94.4	1	1.0	89.1	1.0
9-10	1	1.9	96.3	3	3.0	92.1	3.0
10-11	2	3.7	100.0	8	7.9	100.0	4.0
Total	54	100.0		101	100.0		1.9

Table 12. Mean headings of southbound gray whales by pod size, shorebased observations, January 1987.

Pod Size	No. of Pods	Heading °True North Mean ±
1	22	164.5 ± 26.9
2	13	162.4 ± 34.2
3	14	158.3 ± 18.7
4	1	160.6 -
5	1	138.3 -
Non-Cow/Calves	51	161.6 ± 26.9
Cow/Calves	3	131.8 ± 25.2
Total	54	160.0 ± 27.6

Table 13. Mean speeds of southbound gray whales by pod size, shorebased observations, January 1987.

Pod Size	No. of Pods	Speed (km/hr) Mean ± S.D.
1	15	7.3 ± 2.2
2	11	6.2 ± 2.2
3	10	7.8 ± 3.4
4	1	7.6 -
5	1	11.4 -
Non-Cow/Calves	38	7.2 ± 2.7
Cow/Calves	3	5.0 ± 2.0
Total	41	7.1 ± 2.7

Table 14. Mean dive duration times of southbound gray whales by pod size, shorebased observations, January 1987.

	Long Dives (1-10 min)			Short Dives (0-1.0 min)			All Dives (0-10 min)		
Pod Size	No. of Pods	No. of Dives	Mean ± S.D.	No. of Pods	No. of Dives	Mean ± S.D.	No. of Pods	No. of Dives	Mean ± S.D.
1	19	106	4.6 ± 2.0	14	47	0.5 ± 0.2	19	163	3.1 ± 1.4
2	12	86	3.8 ± 1.1	12	65	0.5 ± 0.2	12	151	2.3 ± 0.7
3	11	82	3.4 ± 0.9	11	134	0.5 ± 0.1	11	216	1.6 ± 0.6
4	1	2	3.8 -	1	14	0.6 -	1	16	1.0 -
Non-Cow/Calves	43	276	4.0 ± 1.6	38	260	0.5 ± 0.2	43	546	2.5 ± 1.3
Cow/Calves	3	25	3.2 ± 0.7	3	22	0.5 ± 0.0	3	47	2.1 ± 0.6
Total	46	301	4.0 ± 1.6	41	292	0.5 ± 0.1	46	593	2.4 ± 1.2

Table 15. Mean respiration rates for southbound gray whales by pod size, shorebased observations, January 1987.

	Respiration Rate (blows/hr)	
Pod Size	No. of Pods	Mean ± S.D.
1	18	23.3 ± 8.9
2	11	19.0 ± 2.9
3	10	20.1 ± 11.6
4	1	24.0 -
Non-Cow/Calves	40	21.3 ± 8.7
Cow/Calves	3	18.5 ± 7.0
Total	43	21.1 ± 8.6

Table 16. A summary of behaviors observed in southbound gray whales, shorebased observations, January 1987.

	Total	% Within Category
Number of Days	6	
Number of Pods	70	
Total Observation Time (hrs)	31.2	
Traveling Mode		
Traveling	730	99.7
Milling	2	0.3
Total	732	100.0
Respiration		
Blows	719	81.2
Blow Mother	6	0.7
Blow Calf	20	2.3
Blow Mother/Calf	7	0.8
Surfacings, No Blows Observed	134	15.1
Total	886	100.0
Surface/Social Behaviors		
No Apparent Behavior	717	97.3
Breaching	14	1.9
Rolling	3	0.4
Headlift	1	0.1
Spyhop	0	0.0
Pods Splitting	0	0.0
Pods Joining	1	0.1
Tail Slap	0	0.0
Tail Lift	0	0.0
Calf Inside Mother	0	0.0
Calf Outside Mother	0	0.0
2 Calves/1 inside and the other outside	0	0.0
Vessel Avoidance	1	0.1
Total	737	100.0
Diving Attitude		
Flukes Lifted	55	7.5
Flukes Not Lifted	676	92.5
Total	731	100.0

One individual in Pod #33 breached 5 times in 73 sec, separated by periods of 7, 7, 19, and 40 sec. The two whales of Pod #66 breached twice, 8 sec apart, although it could not be determined if the breaches involved one or both whales.

Seventeen vessels were seen during the January survey of which 12 were commercial fishing vessels. On six occasions whale and vessels were in close proximity. In only two instances did there appear to be any behavioral response to the presence of the vessels.

The first instance occurred on 20 January 1987, three pods (#37, #38, and #40) were involved in a vessel interaction with a commercial fishing vessel (VC15) (Appendix E-28). The vessel was first sighted 5.5 km offshore, north of Mussel Point at 0812 hrs proceeding south at a speed of 12 km/hr. At 0959 hrs it slowed to a speed of 2.5 km/hr and stopped at 1031 hrs. Pod #37 (five individuals) was sighted at 0955 hrs, traveling behind in an offshore direction, and seaward of VC15 at a speed of 9.5 km/hr. By 1007, however, the pod had reduced its speed to 7.5 km/hr. Pod #37 resumed a more southerly heading between 1007 and 1046 hrs, maintaining a distance of about 700 m offshore of the vessel but at reduced speeds between 3.0 and 3.8 km/hr. Pod #38 (3 whales) was traveling behind and inshore of VC15 at 1000 hrs at a speed of 7.0 km/hr. At 1008 hrs, the whales were about 0.5 km from the vessel, when they made a directional change toward the vessel and slowed to a speed of 2.0 km/hr. At 1014 hrs the whales reversed their direction, headed away from the vessel, while moving south at speeds between 3.8 and 5.0 km/hr. At 1033 hrs, two blows and flukes from a whale were sighted just outside of, and behind the vessel, which had stopped at 1031 hrs. This whale was given a new pod designation; it was the opinion of the observers that this individual had split from Pod #38. While near the vessel, the whale made three, 1-min dives, diverting from its previous heading. It then proceeded offshore and at 1046 hrs joined Pod #37, which was ahead of the fishing vessel.

In summary, Pod #37 slowed when it was traveling near the fishing vessel. Pod #38 exhibited similar slowing and changed its heading at a distance of 0.5 km. Pod #40, which split from Pod #38 resurfaced near the fishing vessel, made several short, erratic dives, and then joined with Pod #37 after passing by the vessel.

The second instance, on 21 January, resulted in whales changing course to avoid an approaching vessel. Pod #72 (two whales) was 3 to 4 km offshore approaching Point Sal (Appendix E-29). At 1413 hrs, a gill netter (VC20) changed its heading from southeast to northwest, thereby moving directly toward Pod #72. As the vessel approached the pod at a speed of 13.4 km/hr, the whales changed course and headed directly offshore. The vessel and the pod were approximately 0.26 km apart when the whales changed course. Just prior to changing course, between 1414 and 1416 hrs, the pod was traveling at 9.6 km/hr. After changing course, the pod slowed to 6.6 km/hr. Between 1423 and 1425 hrs, the pod made a series of three short dives, approximately 0.6 min in duration over a distance of about 66 m and at a speed of 6 km/hr.

AERIAL SURVEYS OF THE NORTHBOUND MIGRATION

Data and frequency distribution graphics from the aerial survey of gray whales are presented by parameter in Appendix D-1 through D-18.

On 26 April 1986 weather conditions were poor and on 27 April only slightly better; however, by 4 May the weather conditions improved to Beaufort 0. Because of inclement weather and sighting conditions, the March 1987 aerial survey was conducted on two seperate, three-day periods, 17-19 and 27-29 March. Flights were conducted between 0900 and 1452 hrs, although flight time varied each day. Survey time totaled 13.6 hrs, averaging 1.9 hrs/survey. Surveys in the morning of 18 March and the afternoon of 29 March were abbreviated because of poor viewing conditions, the result of Beaufort of 4 to 5+ seas. Otherwise, sea state and visibility were sufficient to conduct the surveys.

On 21 May 1987, sea state was very good to excellent, never exceeding Beaufort 3. Sun glare was minimal due to the overcast conditions with ceilings of about 1,200 ft. Surveys were flown in the morning between 0755 and 1040 hrs (2.7 hrs) and in the afternoon from 1250 to 1525 hrs (2.6 hrs).

Nine aerial transect surveys were conducted over a six-day period between 8 March and 16 March 1988. A total of 21.6 hrs were spent over the study area (mean=2.7 hrs/survey); four of the surveys were flown between 0945 and 1235 hrs while five were flown in the afternoon between 1305 and 1820 hrs. Aerial surveys were not conducted in April 1988 because of the paucity of cow/calf pairs.

Between April 1986 and March 1988, 139 pods of gray whales containing 367 individuals were observed in aerial surveys of the northbound migration. Of these, 107 pods (77%) and 281 whales (77%) were within the study area, the remainder were extralimital. The overall mean pod size was 2.7 whales and a mean rate of 6.3 whales/hr was observed (Table 17). About 92% (128) of the pods were non-cow/calf pods of the Phase A migration; the 340 whales in these pods accounted for about 93% of the total whale abundance. Only 11 northbound cow/calf pods (Phase B) were observed and 12 of the 27 individuals (44%) were calves (Appendix D-24).

Twenty-five percent of the 340 individual whales were in pods of three whales, followed by pods of 2 whales (22%), and single whales (11%); the remaining 42% occurred in pods with more than three individuals (Appendix D-24). Two large pods of 14 and 18 individuals occurred during the March 1988 surveys.

SHOREBASED SURVEYS OF THE NORTHBOUND MIGRATION

Weather and sea state, gray whale survey data, frequency distribution by parameter, and vessel and aircraft sightings are presented in Appendix E-1 through E-20.

Shorebased observations of the northbound migration were first conducted from Point Sal from 30 April through 6 May 1986. Forty hours were spent tracking and observing primarily Phase B migrants.

The March 1987 surveys were conducted on 16 and 17 March from both Point Sal and Mussel Point and were characterized by poor to moderate viewing conditions, with high winds and limited offshore visibility. No whales were seen on 16 March and only three pods were tracked (for a short time) on 17 March. Sightings were terminated by noon on both days and field work was discontinued until later in the month. Surveys were resumed on 25 March, when the weather and viewing conditions improved and continued through 29 March. Generally, winds were blowing between 1 and 4 km/hr in the morning and up to 10 km/hr in the afternoon.

Surveys were conducted from Mussel Point on 4 and 6 May and again on 1 and 12 May 1987. Sea state varied from Beaufort 1 to 2, with light to moderate winds and small to medium swells. Visibility was limited by fog in the mornings and early afternoon on three of the four days, with visibility ranging from less than 0.5 to 4.8 km. Observation time averaged 6 hr/day. On 12 May, an oil slick approximately 1.0 to 1.5 m wide and 10 to 13 m long was noted 0.5 km offshore between Mussel Point and Point Sal. The origin of the slick was unknown; it broke up as it neared the shoreline.

Surveys were also conducted 6 to 12 March and 14 to 18 March 1988. Visibility varied between 2.6 and 8.0 km. Sightings were terminated three days when sea state approached Beaufort 4. Sightings were made between 0630 and 1700 hrs and observation time varied between 2.4 and 9.0 hrs, averaging 5.4 hrs/day.

Observers spent 34.2 hrs in the field on 12 April and from 25 to 28 April 1988 searching for cow/calf pairs. Due to extremely bad weather the initial survey was delayed until the last week in April. During the field surveys, visibility ranged from 3.2 to 4.7 km and sea state varied between Beaufort 1 and 3. Additional field days were spent at Point Vicente, Palos Verdes on 30 April and 3 May attempting, unsuccessfully, to locate cow/calf pairs. On 12 May 1988 MBC staff flew in California Department of Fish and Game's Twin Otter aircraft between Long Beach, San Nicolas Island, the Mexican Border, and back up the shoreline to Long Beach; no gray whales were sighted. On 19 and 20 June 1988, Mr. Tom Dohl flew a total of 1.8 hrs over the Point Sal study area, but no gray whales were sighted.

During the three-year study, 217 pods and 371 individual northbound whales were observed between Point Sal State Beach and the Santa Maria River (Table 18). The mean pod size for the entire three-year period was 1.7 whales.

Non-cow/calf pods (Phase A) accounted for 77% of the pods and 70% of the whales seen in the northbound migration (Appendix E-30). Cow/calf pairs (Phase B) were observed only during April and May. The 56 calves observed accounted for about 15% of the total whale abundance for the northbound migration and about 54% of the whales in the Phase B. Most of the cow/calf pods (which included 103 individuals) were observed during the 30 April to 6 May 1986 survey.

PHASE A NORTHBOUND MIGRATION

AERIAL SURVEYS

The distribution of all aerial sightings of Phase A gray whales in 1986, 1987, and 1988 (including extralimital observations) is illustrated in Figures 22 and 23. Data are presented in Appendices D-1 through D-18.

Abundance

During aerial surveys in 1987 and 1988, 95 pods and 254 Phase A whales were observed in the study area (Table 19; Appendix D-25). Two sightings of single whales during the May 1986 aerial survey were not included in data analyses because the flights were not dedicated for the surveys and the complete sampling array could not be occupied. Extralimital sightings in 1987 and 1988 were excluded from analysis.

Table 17. Numbers of northbound gray whales sighted off Point Sal, aerial observations, 1987 to 1988.

Survey	No. of Pods	No. of Whales	Mean Pod Size	Hours of Observation	No. of Pods Observed/Hr	No. of Whales Observed/Hr
March 1987	46	120	2.6	13.6	3.4	8.8
May 1987	10	16	1.6	5.3	1.9	3.0
March 1988	80	227	2.8	21.6	3.7	10.5
Total	136	363	2.7			
Phase A	95	252	2.7	40.5	2.3	6.2
Phase B	9	21	2.3	40.5	0.2	0.5
Total (w/extrapolations)	136	363	2.7	40.5	3.4	9.0
Phase A	126	338	2.7	40.5	3.1	8.3
Phase B	10	25	2.5	40.5	0.2	0.6
Study Area	104	273	2.6	40.5	2.6	6.7

Table 18. Numbers of northbound gray whales sighted and observation rates off Point Sal, shorebased observations, 1986 to 1988.

Survey	No. of Pods	No. of Whales	Mean Pod Size	Hours of Observation	No. of Pods Observed/Hr	No. of Whales Observed/Hr
April/May 1986	48	105	2.2	40.0	1.2	2.6
March 1987	29	60	2.1	31.2	0.9	2.0
May 1987	2	3	1.5	24.5	0.1	0.1
March 1988	123	180	1.5	64.2	1.9	2.8
April 1988	15	23	1.5	34.2	0.4	0.7
Phase A	167	260	1.6	-	-	-
Phase B	50	111	2.2	-	-	-
Total	217	371	1.7	194.1	1.1	1.9

Table 19. Numbers of Phase A gray whales sighted offshore Point Sal, aerial observations, 1986 to 1988.

Survey	No. of Pods	No. of Whales	Mean Pod Size	Hours of Observation	No. of Pods Observed/Hr	No. of Whales Observed/Hr
April/May 1986*	2	2	1.0	2.6	-	-
March 1987	44	113	2.6	13.6	3.2	8.3
May 1987	5	6	1.2	5.3	0.9	1.1
March 1988	77	219	2.8	21.6	3.6	10.1
Total	128	340	2.7	40.5	3.2	8.4
Study Area	95	254	2.7	40.5	2.3	6.3

* Data for April/May 1986 deleted from study area analysis

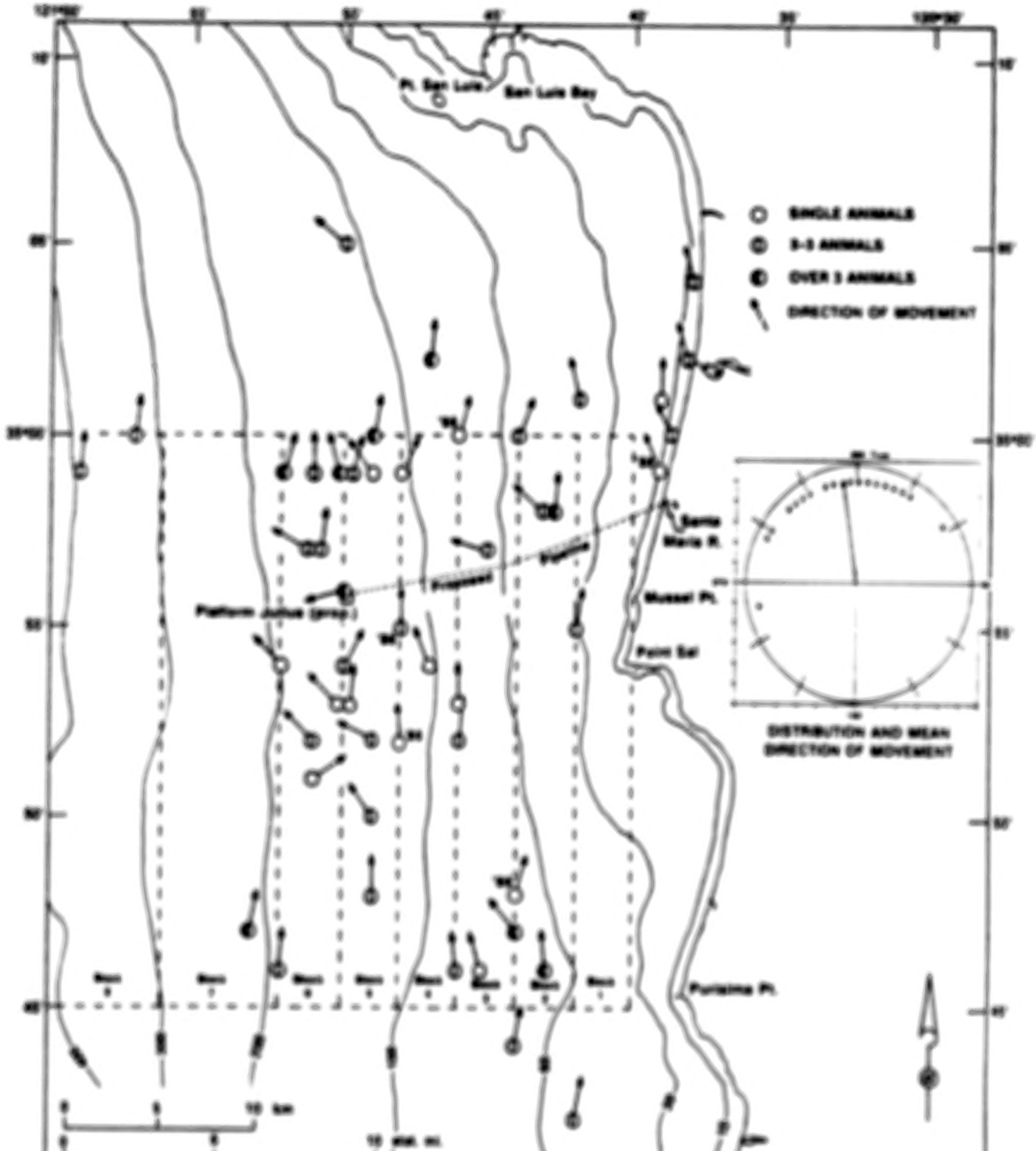

Figure 20. Locations and headings of Phase A gray whale pods, aerial observations, March 1988.

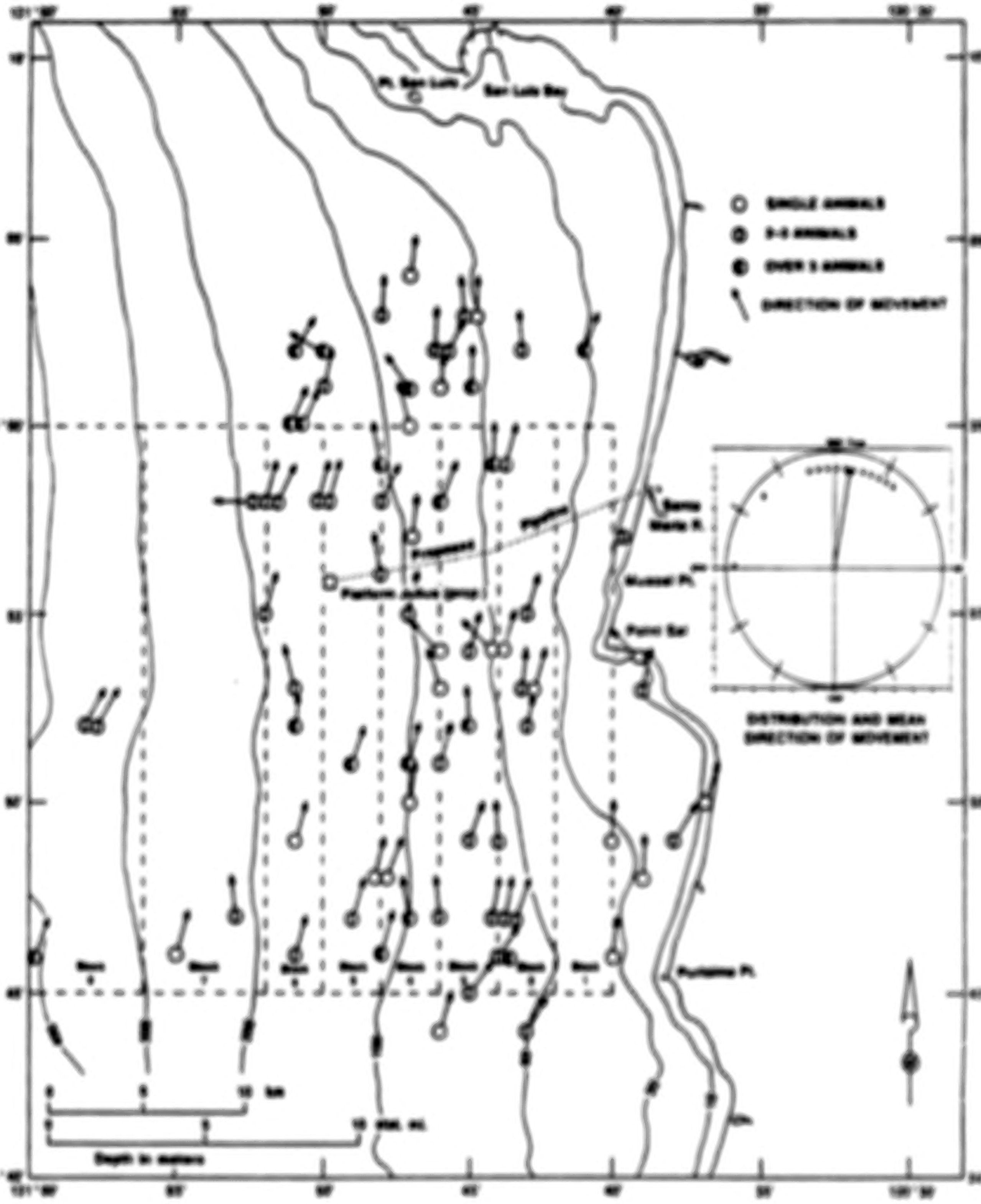

Figure 21. Locations and headings of Phase A gray whale pods, aerial observations, 1986-1987.

The 95 pods (for simplicity, a pod is defined as an observational unit consisting of one or more individual gray whales) analyzed averaged 2.7 whales/pod. Most whales traveled in pods containing 2, 3, or 4 whales, although pod size ranged from 1 to 18 whales. The greater number of pods and whales seen in 1988 was apparently due to the increased amount of observation time (Table 19); when standardized by observation time (and by excluding 1 pod of 18 whales), the numbers of pods and of whales/hr during the two March surveys were similar. The rate at which whales were observed in the Point Sal survey area was greater during the March 1988 survey (10.2 whales/hr) than in March 1987 (8.3 whales/hr). The numbers of pods and individuals decreased as the Phase A migration progressed (Table 19).

In March 1987, pod size ranged from 1 to 7 whales, with a mean of 2.6 whales/pod; in May 1987 the mean pod size was 1.3 (Table 20). In March 1988, pod size averaged 2.8 and ranged from 1 to 18. The 26 singles accounted for 27% of the pods and 10% of the whales. Eighty-eight percent of the pods and 87% of the whales were sighted in Blocks 2 through 6 (Table 20). The mean pod size ranged from 1.3 whales/pod in Block 1 (nearest shore) to 3.7 and 3.6 whales/pod in the two blocks most distant from shore (Table 20).

Mean density estimates by survey block for all Phase A whales observed during 1987 and 1988 are given in Appendix D-26. Overall mean density was 0.014 whales/km^2, and ranged from 0.002 in Block 1 to 0.022 whales/km^2 in Blocks 3, 4, and 5. The density of pods and individuals were the same during March 1987 and 1988, however, were lower in May 1987 (Table 21).

Migration Corridors

During Phase A whales were sighted between 3.3 and 32.5 km from shore (Figures 20 and 21), at a mean of 14.1 km offshore (Table 22). The distance offshore (in 6 km-wide migration blocks) as a function of pod size is depicted in Appendix D-27. Mean pod size was significantly correlated with distance offshore ($r=0.60$, $df=15$, $p<0.05$). The mean distance of singles (12.5 km for $n=26$) and the mean distance of whales traveling in pods of two or more individuals (14.7 km for $n=69$) were not significantly different ($t=2.26$, $df=93$, $p>0.05$).

The numbers of pods and whales as a function of distance from shore are presented in Appendix D-28. The bulk of migrants traveled within 20 km of shore. Non-cow/calves apparently traveled farther offshore in the migration season than later; very few whales were seen in the May survey (Table 23).

Ninety-two percent of the pods and 89% of the whales occurred within the 200 m isobath (Figures 20 and 23 and Table 20). The distribution of gray whales with respect to water depth was similar in the March and May surveys. Mean pod size was significantly correlated with water depth ($r=0.831$, $df=5$, $p<0.05$), ranging from 2.0 animals/pod at depths between 10 and 30 m to 6.0 whales/pod at depths over 400 m.

Direction of Movement

The headings of Phase A whales in 1987 and 1988 are illustrated in Appendix D-29. The mean heading was 2.8 ± 24.9° True (Table 24), very close to directly north, and individual headings varied from southwest (240° True) to northeast (60° True). Sixty-five percent of the 95 headings formed a mode between 20 and 40° True (Appendix D-29). By survey, mean headings varied from 351° True in March 1987 to about 10° True in March 1988; similar variation was noted during surveys conducted in May 1986 and 1987.

SHOREBASED SURVEYS

Weather and sea state, survey data, frequency distribution by parameter, and vessel and aircraft sightings are presented in Appendices E-1 through E-20.

Abundance

During the Phase A migrations between 1986 and 1988, 167 pods and 260 whales were observed from shore stations in the study area (Table 25). The rate of sightings averaged 1.0 pod and 1.5 whales/hr. The

Table 20. Distribution of Phase A non-cowcalf gray whales by distance from shore and by water depth, aerial observations, 1987 to 1988.

		Pods			Whales			
	Intervals	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Block	(km)							
1	0- 3.2	3	3.2	3.2	4	1.6	1.6	1.3
2	3.2- 6.4	20	21.1	24.2	54	21.3	22.8	2.7
3	6.4- 9.6	15	15.8	40.0	32	12.6	35.4	2.1
4	9.6-12.8	16	16.8	56.8	50	19.7	55.1	3.1
5	12.8-16.0	15	15.8	72.6	39	15.4	70.5	2.6
6	16.0-19.2	18	18.9	91.6	46	18.1	88.6	2.6
7	19.2-28.6	3	3.2	94.7	11	4.3	92.9	3.7
8	28.6-32.0	5	5.3	100.0	18	7.1	100.0	3.6
Depth	(m)							
A	10-36	1	1.1	1.1	2	0.8	0.8	2.0
B	30-60	13	13.7	14.7	30	11.8	12.6	2.3
C	60-100	26	27.4	42.1	60	23.6	36.2	2.3
D	100-200	47	49.5	91.6	133	52.4	88.6	2.8
E	200-300	3	3.2	94.7	11	4.3	92.9	3.7
F	300-400	4	4.2	98.9	12	4.7	97.6	3.0
G	400+	1	1.1	100.0	6	2.4	100.0	6.0
Total		95	100.0		254	100.0		2.7

Table 21. Densities of Phase A gray whales sighted by survey, aerial observations, 1987 to 1988.

		Number of Pods/km^2		Number of Whales/km^2	
Survey	Area (km^2)	No. of Pods	Mean ± S.D.	No. of Whales	Mean ± S.D.
March 1987	5676.75	35	0.006 ± 0.006	91	0.016 ± 0.018
May 1987	2064.00	4	0.002 ± 0.003	5	0.002 ± 0.005
March 1988	9288.00	56	0.006 ± 0.006	158	0.017 ± 0.017
Mean	5676.25	31.7	0.006 ± 0.006	84.7	0.015 ± 0.016

Table 22. Distance from shore of Phase A gray whales by pod size, aerial observations, 1987 to 1988.

Distance from Shore (km)								
	1987			1988			1987-1988 Combined	
Pod Size	n	Mean ± S.D.	Pod Size	n	Mean ± S.D.	Pod Size	n	Mean ± S.D.
1	12	13.7 ± 3.2	1	14	11.5 ± 6.9	1	26	12.5 ± 5.6
2	10	14.0 ± 5.7	2	17	12.9 ± 4.9	2	27	13.3 ± 5.1
3	9	18.1 ± 8.1	3	12	14.7 ± 8.0	3	21	16.2 ± 8.0
4	5	13.6 ± 4.6	4	5	14.1 ± 5.2	4	10	13.9 ± 4.6
5	2	15.0 ± 7.8	5	6	11.9 ± 2.7	5	8	17.7 ± 4.0
7	1	24.0 -	6	1	33.0 -	6	1	33.0 -
			18	1	15.0 -	7	1	24.0 -
						18	1	15.0 -
Total	39	15.1 ± 5.9		56	13.3 ± 6.5		95	14.1 ± 6.2

Table 23. Mean distance offshore of Phase A gray whales, aerial observations, 1987 to 1988.

		Distance From Shore (km)
Survey	No. of Pods	Mean ± S.D.
March 1987	35	15.5 ± 6.0
May 1987	4	11.5 ± 1.2
March 1988	56	13.3 ± 6.5
1987-1988	95	14.1 ± 6.2

Table 24. Mean course headings (°True) of northbound gray whales by survey and pod size, aerial observations, 1987 to 1988.

		Survey				Pod Size	
Survey	n	Mean Heading	± S.D.	Pod Size	n	Mean Heading	± S.D.
				1	27	2.4	20.7
				2	27	5.7	24.6
March 1987	35	350.5	31.2	3	21	0.0	29.2
May 1987	4	7.3	8.8	4	9	358.7	33.1
March 1988	56	9.5	18.3	5	8	3.9	18.2
				6	1	21.0	-
				7	1	353.5	-
				10	1	16.0	
1987-1988	95	2.8	24.7		95	2.8	24.7

Table 25. Numbers of Phase A gray whales sighted by survey, shorebased observations, 1986 to 1988.

Survey	No. of Pods	No. of Whales	Mean Pod Size	Hours of Observation	No. of Pods Observed/hr	No. of Whales Observed/hr
May 1986	2	2	1.0	40.0	0.05	0.05
March 1987	29	60	2.1	31.2	0.93	1.92
May 1987	2	3	1.5	24.5	0.08	0.12
March 1988	123	180	1.5	64.2	1.92	2.80
April 1988	11	15	1.3	34.2	0.32	0.44
Total	167	260	1.6	169.6	1.98	1.53

tracks and behavior of 126 pods and 215 whales were recorded during 170 hrs of field observations. The mean pod size for all Phase A *migrations* was 1.6 whales (Table 25). The rate of sightings of pods and individuals was substantially higher in March than in April-May.

Migration Corridors

Phase A whales were observed between 0.3 and 11.7 km from the shore in May 1986, March 1987, and March-April 1988. The mean distance offshore of the 126 pods was 3.1 km (Table 26). Most (76%) of the whales observed were within 5 km of shore (Table 27).

Table 26. Distance from shore of Phase A gray whales by survey and pod size, shorebased observations, 1986 to 1988.

	Distance From Shore (km)							
	May 1986		March-May 1987		March-April 1988		1986-1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
1	1	0.8 -	7	4.7 ± 3.1	53	2.6 ± 2.3	61	2.8 ± 2.5
2			13	3.8 ± 2.6	37	2.9 ± 1.5	51	3.1 ± 1.9
3			2	5.5 -	7	3.6 ± 2.2	9	4.0 ± 2.2
4			2	6.5 -	3	4.0 ± 1.6	4	4.7 ± 1.9
8			1	9.8 -			1	9.8 -
Total	1	0.8 -	25	4.5 ± 2.9	100	2.8 ± 2.1	126	3.1 ± 2.4

Table 27. Distance from shore of Phase A gray whales, shorebased observations, 1987 to 1988.

	Pods			Whales			
	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Distance (km)							
0-1	28	22.2	22.2	41	19.2	19.2	1.5
1-2	25	19.8	42.1	41	19.2	38.3	1.6
2-3	14	11.1	53.2	21	9.8	48.1	1.5
3-4	19	15.1	68.3	28	13.1	61.2	1.5
4-5	15	11.9	80.2	33	15.4	76.6	2.2
5-6	8	6.3	86.5	17	7.9	84.6	2.1
6-7	9	7.1	93.7	16	7.5	92.1	1.8
7-8	4	3.2	96.8	5	2.3	94.4	1.3
8-9	1	0.8	97.6	2	0.9	95.3	2.0
9-10	2	1.6	99.2	9	4.2	99.5	4.5
10-11	0	0.0	99.2	0	0.0	99.5	0.0
11-12	1	0.8	100.0	1	0.5	100.0	1.0
Total	126	100.0		214	100.0		1.7

Distance offshore was positively correlated with pod size ($r=0.286$, $df=123$, $p<0.01$), single whales averaging about 2.8 km offshore and pods of 4 averaging about 4.7 km. Singles and pairs were uncommon beyond 6 km from shore (Appendix E-31). When pods greater than 6 km from shore increased with distance offshore are combined, mean pod size distance ($r=0.794$, $df=5$, $p<0.05$), ranged from 1.3 whales/pod at 0 to 1 km offshore to 2.1 whales/pod at 6 or more km from shore.

Relationships to Coastline and Bathymetry

The relationships between the gray whale migratory corridor, the coastline, and local bathymetry are illustrated in Figure 24. Gray whales generally approached Point Sal from the southwest converging offshore of the headland at water depths of 10 to 60 m. Between Point Sal and Mussel Point they appeared to follow the 30 m isobath closely, which is further offshore to the north. North of Mussel Point, most whales traveled further offshore and over increasingly deeper water as they headed northwest across San Luis Bay toward the headland at Point Buchon. Seven pods, however, changed headings as they passed Mussel Point and moved closer to shore, in or just outside the surf zone to at least the Santa Maria River.

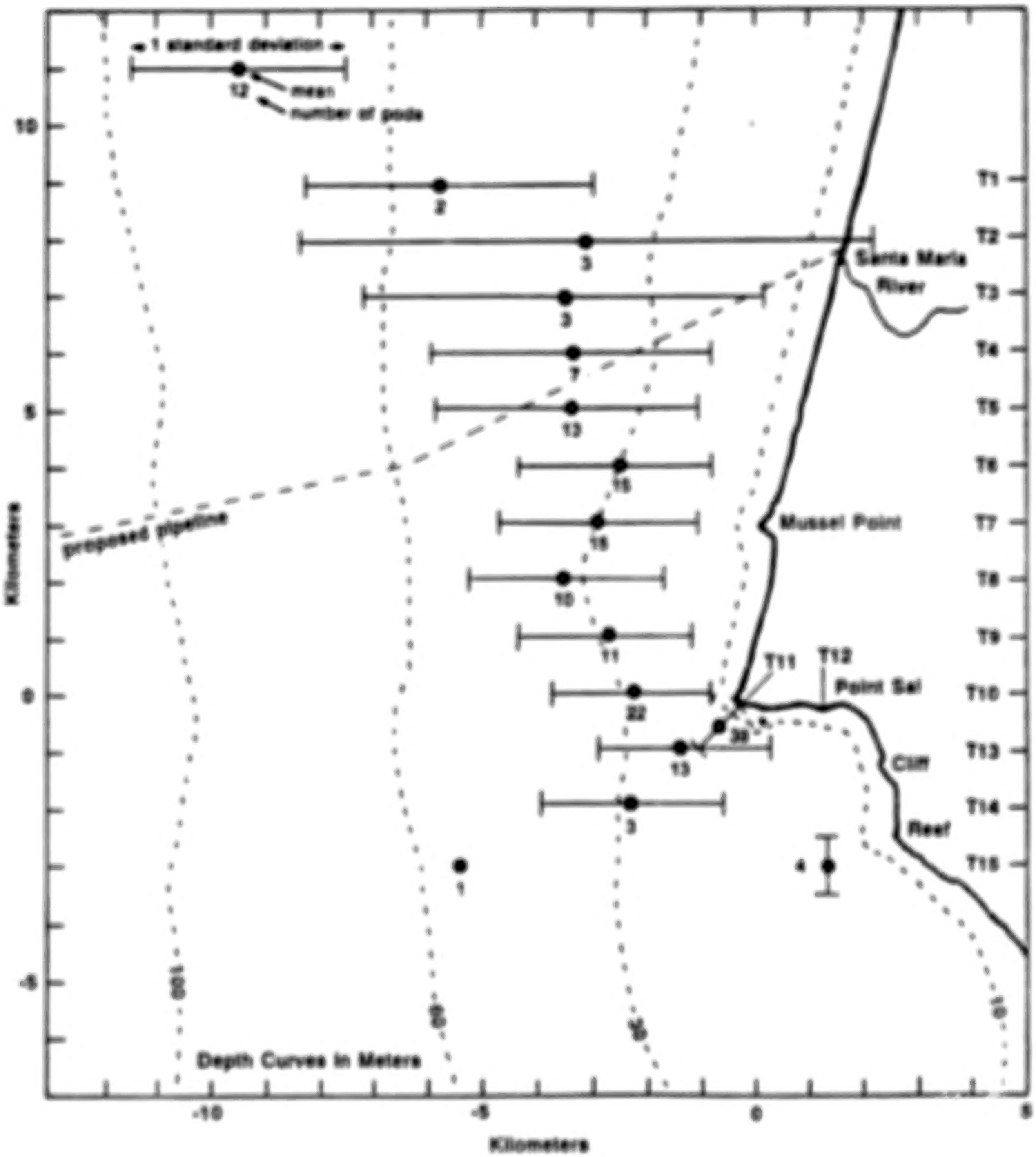

Figure 22. Mean migration corridor of Phase A gray whales in relation to the coast and bathymetry, shorebased observations, 1984-1985.

Table 28. Mean headings (°True) of Phase A gray whales, by survey and pod size, aerial observations, 1987 to 1988.

	Direction of Movement (°True)					
	1987		1988		1987-1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
1	5	311.3 ± 55.5	45	323.4 ± 41.0	50	322.5 ± 42.8
2	13	339.0 ± 55.9	34	317.4 ± 50.2	47	322.6 ± 52.4
3	2	56.4 ± 57.0	5	321.0 ± 21.8	7	333.5 ± 46.9
4	1	337.7 -	3	347.2 ± 34.6	4	344.5 ± 30.2
8	1	27.8 -			1	27.8 -
Total	22	341.5 ± 57.2	87	322.1 ± 44.1	109	325.0 ± 47.4

Table 29. Mean swimming speeds of Phase A gray whales by pod size and survey, shorebased observations, 1986 to 1988.

	Speed (km/hr)							
	May 1986		March-May 1987		March-April 1988		1986-1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
1	1	4.3 -	3	2.1 ± 0.4	54	5.1 ± 1.8	58	4.9 ± 1.9
2			9	5.6 ± 2.8	39	5.3 ± 2.9	48	5.3 ± 2.9
3			2	6.8 ± 1.4	5	4.5 ± 1.6	7	5.2 ± 1.9
4			1	4.7 -	3	4.4 ± 1.4	4	4.5 ± 1.4
8			1	11.7 -			1	11.7 -
Total	1	4.3 -	16	5.4 ± 3.0	101	5.1 ± 2.3	118	5.1 ± 2.4

Direction of Movement

Appendices E-32 and E-33 illustrate the pod tracks of the 1987 and 1988 Phase A migration and the coastline; Appendix E-24 shows the frequency distribution of course headings. The mean heading of all Phase A pods were 325° True, 342° True in 1987 to 322° True in 1988 (Table 28). The range of swimming directions was wide (Appendix E-34). Outliers were pod headings recorded during milling activity.

Swimming Speed

During the 1986, 1987, and 1988 surveys the overall mean swimming speed of 118 pods was 5.1 km/hr (Table 29). Swimming speeds were distributed normally: 42% were between 4 and 6 km/hr. Swimming speeds did not differ significantly between years, averaging 5.4 km/hr in 1987 and 5.1 km/hr in 1988. Swimming speeds of pods of 1 to 4 whales, combined for 3 years, were similar of all pod sizes (Table 29).

Dive Duration

The mean dive time for 98 pods of Phase A migrants was 2.4 min ($n = 2{,}136$; Table 30). Sixty-five percent of the dives were under 1.0 min long (Appendix E-35). The 35% of the dives lasting longer than 1.0 min averaged 4.0 min in duration. Dive duration was inversely related to pod size ($r=0.322$, $p<0.01$), ranging from 3.1 min for singles to 2.4 min for a single pod of eight. The long dives of single animals were also significantly longer than for whales traveling in groups (4.4 min vs. 3.6 min); ($P<0.05$).

Table 30. Duration of dives by Phase A gray whales by pod size and survey, shorebased observations, 1986 to 1988.

	Long Dives (1-10 min)			Short Dives (0-1.0 min)			All Dives (0-10 min)		
Pod Size	No. of Pods	No. of Dives	Mean ± S.D.	No. of Pods	No. of Dives	Mean ± S.D.	No. of Pods	No. of Dives	Mean ± S.D.
1986									
1	1	4	3.1 -	1	1	0.4 -	1	5	2.5 -
1987									
1	1	4	6.2 -				1	4	6.2
2	10	109	3.9 ± 2.0	8	257	0.4 ± 0.1	10	366	2.6 ± 2.5
3	2	55	2.4 ± 0.1	2	126	0.4 ± 0.0	2	181	0.9 ± 0.2
4	1	22	3.4 -	1	95	0.3 -	1	117	0.9 -
8	1	15	3.2 -	1	130	0.3 -	1	145	0.6 -
Total	15	205	3.7 ± 1.8	12	608	0.4 ± 0.1	15	813	2.3 ± 2.4
1988									
1	42	235	4.4 ± 1.7	35	169	0.5 ± 0.2	42	404	3.0 ± 1.5
2	32	225	3.6 ± 1.2	30	414	0.4 ± 0.1	32	639	1.9 ± 1.3
3	5	70	3.5 ± 1.0	5	161	0.3 ± 0.1	5	231	1.3 ± 0.5
4	3	14	4.8 ± 1.2	3	31	0.4 ± 0.1	3	45	2.3 ± 1.2
Total	82	544	4.0 ± 1.5	73	775	0.4 ± 0.2	82	1318	2.4 ± 1.5
1986 to 1988 Combined									
1	44	242	4.4 ± 1.7	36	170	0.4 ± 0.2	44	412	3.1 ± 1.6
2	42	334	3.6 ± 1.4	38	671	0.4 ± 0.1	42	1005	2.0 ± 1.7
3	7	125	3.2 ± 1.0	7	287	0.3 ± 0.1	7	412	1.2 ± 0.5
4	4	36	4.5 ± 1.2	4	126	0.4 ± 0.1	4	162	2.0 ± 1.2
8	1	15	3.2 -	1	130	0.3 ± -	1	145	0.6 -
Total	98	752	4.0 ± 1.6	86	1384	0.4 ± 0.2	98	2136	2.4 ± 1.7

Table 31. Respiration rates of Phase A gray whales, by pod size and survey, shorebased observations, 1986 to 1988.

	Respiration Rate (blows/hr)							
	May 1986		March-May 1987		March-April 1988		1986-1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
1	1	28.4 -	1	16.2 -	43	22.5 ± 9.1	45	22.5 ± 9.0
2			9	21.4 ± 5.9	31	20.0 ± 9.9	40	20.3 ± 9.2
3			2	27.0 ± 8.3	5	18.1 ± 4.7	7	20.7 ± 7.2
4			1	13.6 -	2	11.4 ± 3.2	3	12.1 ± 2.8
8			1	14.6 -			1	14.6
Total	1	28.4	14	20.8 ± 6.8	81	21.0 ± 9.3	96	21.2 ± 9.0

There was little variation in short, long, and mean dive times between 1987 and 1988 (Table 30). Short dives and mean dives varied by 0.1 min and long dives by 0.3 min between years. The diving patterns for five randomly selected singles were characterized by periods of long dives followed by a series of short dives (Appendix E-36).

Respiration Rates

The mean respiration rate of Phase A pods was 22.0 blows/hr; 76% of the individuals blew between 10 and 30 times/hr. The mean rate by year varied only slightly, 20.8 blows/hr in 1987 and 21.0 blows/hr in 1988 (Table 31). The respiration rates among pod sizes ranged from 22.5 to 12.1 blows/hr for pods of 1 to 4 whales, respectively. A single pod of 8 averaged 14.6 blows/hr. Respiration rates for pods containing 4 and 8 whales were approximately 30% shorter than for smaller sized pods, suggesting that observers had difficulty tracking single individuals in pods of multiple individuals.

There was no relationship between mean respiration rates and swimming speeds ($r=0.021$, $df=30$, $p>0.05$). However, the mean respiration rate decreased significantly with increasing dive durations ($r=0.489$, $df=91$, $p<0.01$) as would generally be expected (Appendix E-37).

Behavior

Table 32 summarizes the frequency of behaviors observed for all surveys; annual data are presented in Appendix E-38). The frequency of various behaviors differed among surveys. Most observations were made on traveling whales that exhibited little activity other than respiration.

Twelve percent of all pods seen exhibited milling behavior. Most surface and social behaviors occurred when whales were milling. Several pods exhibited gradations in behavior between milling and traveling which were recorded as either milling or traveling. These included "lollygagging" (moving very slowly but with no apparent direction) and "drifting" (lying on the surface).

Table 32. A summary of behaviors observed in Phase A gray whales, shorebased observations, 1986 to 1988.

	Total	% within Category
Number of Days	27	
Number of Pods	161	
Total Observation Time (hr)	169.6	
Traveling Activity		
Traveling	1762	73.8
Milling	627	26.2
Total	2389	100.0
Respiration (blows)		
Blows	2330	96.8
Blow Mother	0	0.0
Blow Calf	0	0.0
Blow Mother/Calf	0	0.0
Surfacings, No Blows Observed	77	3.2
Total	2407	100.0
Surface/Social Behaviors		
No Apparent Behavior	1958	82.2
Breaching	27	1.1
Rolling	346	14.5
Headlift	30	1.2
Spyhop	6	0.3
Pod Splitting	3	0.1
Pods Joining	8	0.3
Tail Slap	3	0.1
Tail Lift	2	0.1
Calf Inside Mother	0	0.0
Calf Outside Mother	0	0.0
2 Calves/1 inside and the other outside	0	0.0
Vessel Avoidance	1	<0.1
Total	2384	100.0
Diving Attitude		
Flukes Lifted	63	3.1
Flukes Not Lifted	1995	96.9
Total	2058	100.0

Lollygagging was seen only during 1987: on 17 March in a pod of two whales 0.4 km off Point Sal, and on 25 March in a pod of four whales 6.9 km off Mussel Point. Drifting was observed 4.3 km off Mussel Point on 26 March in a pod of 3 whales), and 6 km offshore on 27 March in a pod of 4 whales).

The most frequently observed surface behavior was rolling, followed by headlifts, breaches; a few tail slaps, and tail lifts were also observed. Except for breaches, these behaviors were observed in pods of 2 or more whales. Breaching usually took place while whales were moving at a steady speed. Of 27 breaches observed, 17 were made while whales were traveling and 10 when they were milling. Whales breached close to shore off Lion Rock, in the surf zone near the Santa Maria River, and at distances of 6.6 km offshore.

Collectively, these behaviors have been characterized by other field observers as "frolicking" (Poole, pers. comm.), and although many are common during courtship, no direct evidence of sexual behavior was observed at Point Sal. Five pods frolicked in March 1987 and two in March 1988 at distances of 2.5 to 6.9 km from shore between Point Sal and the Santa Maria River.

Eight aircraft were observed, including military helicopters that flew over the water and shore at altitudes of 150 to 300 m, an MMS helicopter shuttling personnel to offshore platforms, and other military aircraft. There were no instances in which observers detected a reaction by whales to the aircraft. Small recreational and commercial fishing vessels (crabbers and gill-netters) were common (38 of 50 vessels) during the northbound surveys. Larger vessels, including tankers, tugs, and barges, were seen in the shipping lanes but out of range for tracking.

In only one instance were Phase A whales approached by a vessel. At 1130 hrs on 27 March 4.3 km northwest of Mussel Point, the commercial fishing vessel *Elenore Marie* approached two whales which were milling and frolicking. Observers noted that the vessel turned away, stopped, and re-approached the whales several times, apparently to watch. The whales did not appear to respond to the activity, but continued to mill about for several minutes after the vessel had moved south. After the encounter, the whales moved northeast toward the Santa Maria River, where they continued to frolic.

Interactions With Other Cetaceans

Bottlenose dolphins (*Tursiops truncatus*) were observed traveling in proximity to gray whales on two occasions. On 12 March 1988, a single dolphin was seen with two juvenile gray whales in the surf zone between Mussel Point and the Santa Maria River. At the time, the whales alternated between traveling and milling, engaging in rolling and headlift behaviors.

Six bottlenose dolphins were seen traveling with a single juvenile gray whale along the surf-line 1.6 km north of Mussel Point on 14 March 1988. Shortly afterwards, the gray whale breached five times and spyhopped while moving upcoast.

PHASE B NORTHBOUND MIGRATION

AERIAL SURVEYS

Raw data and frequency distributions from aerial surveys are presented in Appendices D-1 through D-18.

Abundance

Phase B pods (cow/calf pairs) were observed during aerial surveys in March 1987 and 1988, and in May 1986 and 1987 (Table 33). Nine pods and 22 whales, (11 of which were calves) were seen during the three-year study. Cow/calf pods averaged 2.6 whales/pod, and consisted of either one cow/calf pair or two cows and two calves.

Most pods and whales were within Block 3, 6.4 to 9.6 km from shore (Table 34). Distribution and headings for all observations are shown in Figure 23. The mean density of cows and calves in the study area was 0.003 whales/km^2 (Appendix D-30). Density ranged from 0.001 whales/km^2 in March 1988 to 0.006 whales/km^2 in May 1987. Pod densities ranged from less than 0.001 pods/km^2 in Block 5 to 0.005 in Block 1 (Appendix D-30) with a mean of 0.001 pods/km^2. The highest density occurred during May 1987 (Appendix D-31).

Table 33. Numbers of Phase B gray whales sighted during aerial survey, 1986 to 1988. Data for single extralimital sightings deleted from area analysis.

Survey	No. of Pods	No. of Whales	Mean Pod Size	Hours of Observation	No. of Pods Observed/hr	No. of Whales Observed/hr
May 1986	1	2	2	2.6	0.38	0.77
March 1987	1	4	4	13.6	0.07	0.29
May 1987	5	10	2	5.3	0.94	1.89
March 1988	2	6	3	21.6	0.09	0.28
Total Study Area	9	22	2.4	43.1	0.21	0.51

Table 34. Distribution of Phase B gray whales by distance from shore and by water depth, aerial observations, 1986-1988.

		Pods			Whales			
		n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Block	(km offshore)							
1	0- 3.2	3	33.3	33.3	6	26.1	26.1	2.0
2	3.2- 6.4	1	11.1	44.4	2	8.7	34.8	2.0
3	6.4- 9.6	4	44.4	88.9	11	47.8	82.6	2.8
4	9.6-12.8	0	0.0	88.9	0	0.0	82.6	0.0
5	12.8-16.0	1	11.1	100.0	4	17.4	100.0	4.0
6	16.0-19.2	0	0.0	100.0	0	0.0	100.0	0.0
7	19.2-28.6	0	0.0	100.0	0	0.0	100.0	0.0
8	28.6-32.0	0	0.0	100.0	0	0.0	100.0	0.0
Total		9	100.0		23	100.0		2.6
Depth	(m)							
	10-30	2	22.2	22.2	4	17.4	17.4	2.0
	30-60	2	22.2	44.4	4	17.4	34.8	2.0
	60-100	4	44.4	88.9	11	47.8	82.6	2.8
	100-200	1	11.1	100.0	4	17.4	100.0	4.0
	200-300	0	0.0	100.0	0	0.0	100.0	0.0
	300-400	0	0.0	100.0	0	0.0	100.0	0.0
	400+	0	0.0	100.0	0	0.0	100.0	0.0
Total		9	100.0		23	100.0		2.6

Migration Corridors

Cow/calf pairs were seen as close as 2.5 km from shore and as far offshore as 15.0 km with a mean distance offshore of 8.0 km (Table 35). Forty-four percent of the pods and 34.8% of the whales were within 8 km of shore. Pod size increased with distance offshore (Appendix D-32).

Cow/calves traveled farther offshore in March than later in the migration, during May. All Phase B animals observed traveled in water less than 200 m deep (Figure 23 and Table 34); 44.4% of the pods and 47.8% of the whales were at depths between 60 m and 100 m.

Table 35. Distance offshore of Phase B gray whales, aerial observations, 1987-1988.

Survey	No. of Pods	Distance from Shore (km) Mean ± S.D.
May 1986	1	11.1 -
March 1987	2	10.4 ± 1.3
May 1987	5	5.1 ± 2.6
March 1988	2	13.0 ± 2.8
1987-1988	9	8.0 ± 4.2

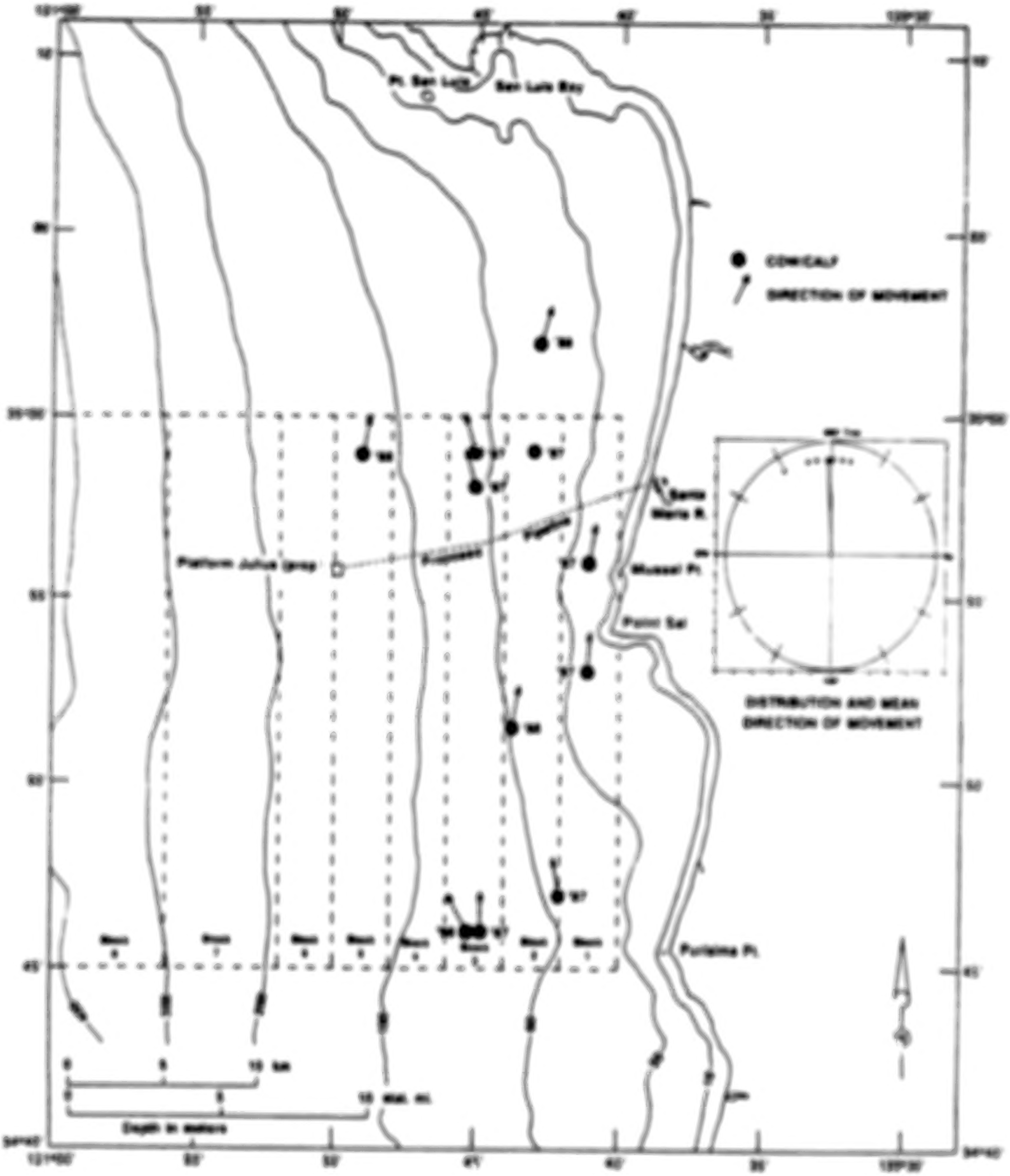

Figure 23. Locations and headings of Phase B gray whale pods, aerial observations, 1987-1988.

Direction of Movement

The mean heading of northbound, Phase B whales during the 1987 and 1988 migration was nearly due north, 355°True (Table 36). Individual pod headings ranged from 340° to 011°True, with the majority between 330° and 030°True. The mean heading was more westerly during the early part of the migration (March of both years) than during the latter part of the migration, May 1988.

SHOREBASED SURVEYS

Weather and sea state, survey data, frequency distribution graphics by parameters, and vessel and aircraft sightings obtained during shorebased studies of Phase B migrations are presented in Appendices E-1 through E-20.

Table 36. Mean headings of Phase B gray whales by survey, aerial observations, 1986 to 1988.

		Heading (°True)	
Survey	No. of Pods	Mean Heading	± S.D.
May 1986	1	5.0	-
March 1987	2	353.5	7.5
May 1987*	4	358.5	10.3
March 1988	2	351.0	10.9
1987-1988	8	355.4	13.7

* Excludes one cow/calf pair with no heading data

Abundance

Totals of 50 pods and 111 whales were tracked through the survey area in 1986 and 1988 (Table 37). Most Phase B pods consisted of a single cow and her calf. Other combinations included one pod with one adult and two calves, and five pods with two adults and two calves. Average pod size was 2.2 whales.

Most sightings of cow/calf pairs were made during 1986 (Table 37). Averages of 1.2 pods/hr and 2.6 whales/hr were recorded. Few sightings of cow/calf pairs were made in 1988; in 34.2 hrs of observation on 12 April and 25-28 April only four pairs were sighted in the study area.

Migration Corridors

The distance offshore of cow/calves by pods (55) and numbers of whales (129) is given in Appendix E-39. Eighty of the whales were within 0.5 km. Cow/calves stayed extremely close to shore during both 1986 and 1988, their average distance from shore being 0.4 km (Table 38). However, individual pods were sighted as near as 20 m from rocky headlands near Reef and Point Sal, and as distant as 2 km offshore north of Point Sal. The mean distances from shore for different pod sizes and surveys varied only slightly, ranging from 0.4 to 0.7 km.

Table 37. Numbers of Phase B gray whale pods sighted by survey, shorebased observations, 1986 and 1988.

Survey	No. of Pods	No. of Whales	Mean Pod Size	Hours of Observation	No. of Pods Observed/hr	No. of Whales Observed/hr
Apr-May 1986	46	103	2.2	40.0	1.2	2.6
Apr 1988	4	8	2.0	34.2	0.1	0.2
Total	50	111	2.2	74.2	0.7	1.5

Table 38. Distance from shore of Phase B gray whales by survey and pod size, shorebased observations, 1986 and 1988.

	Distance from Shore (km)					
	1986		1988		1986-1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
2	42	0.4 ± 0.2	4	0.5 ± 0.3	46	0.4 ± 0.2
3	1	0. -			1	0.5 -
4	7	0. ± 0.1			7	0.4 ± 0.1
6	1	0. -			1	0.7 -
Total	51	0.4 ± 0.2	4	0.5 ± 0.3	55	0.4 ± 0.2

Relationships to Coastline and Bathymetry

Figure 24 illustrates the mean distance from shore of northbound cow/calves along east-west transects between Reef and the Santa Maria River. During the 1986 migration, the cow/calves were closest to shore (0.4 km) near Reef and Point Sal. The corridor was widest and farthest from shore (0.8 km) in the embayment between these two headlands. Most pods were over water depths of 5 to 10 m along this segment of coastline.

Cow/calf movements between Lion Rock and Point Sal were documented in detail. Of the 36 pods tracked to Lion Rock (Figure 24), 5 traveled inside of Lion Rock, along the 5 m isobath and 31 followed a route seaward of Lion Rock, along the 10 m isobath, 0.2 to 0.4 km offshore. Of the latter, 25 stayed inshore of a small unnamed reef at the tip of Point Sal (inside the 10 m isobath) and 6 pods went seaward of the reef, in 10 to 30 m of water.

In 1988, 4 cow/calf pairs were tracked north of Point Sal, past Mussel Point to the Santa Maria River as far as 2 km from shore. One pair made a wide turn off Point Sal along the 20 m isobath, while another moved upcoast in the surf line (Appendix E-40). The 3 cow/calf pairs tracked between Mussel Point and the Santa Maria River all traveled between the surf zone and the 10 m isobath, at distances of 0.3 to 0.35 km from shore.

Direction of Movement

Cow/calves made frequent changes in direction as they traveled along the coast between Reef and the Santa Maria River. Therefore, the mean headings of these pods were not calculated.

Swimming Speed

Overall, cow/calf pods traveled at an average speed of 5.0 km/hr (Table 39). Thirty percent of the pods were measured at speeds between 4.0 and 5.0 km/hr. The average speed of the 49 cow/calf pairs in 1986, and of 4 pairs in 1988 was 4.9 km/hr.

Dive Duration

The frequency distribution of 1,046 dives was strongly skewed to the right and 48% of the dives being a minute or less in duration (Appendix E-41). The duration of dives by cow/calf pods averaged 2.2 min. The mean duration of short dives (less than 1.0 min) was 0.5 min and the mean duration of long dives was 3.2 min (Table 40). Surface and diving sequences of 5 cow/calf pairs were irregular (Appendix E-42).

Respiration Rates

The 21 Phase B pods averaged 29.6 blows/hr (Table 41), ranging from 10.0 to 77.0, approximately 40% of the rates were between 20 and 30 blows/hr. Mean respiration rates and swimming speeds of cow/calf pairs were not correlated, but there was a tendency for breathing rates to decrease as dive times increased (Appendix E-43).

Behavior

A total of 1,060 sightings of cow/calf pairs were recorded as "traveling" with no other specific behaviors exhibited (Table 42, Appendix E-44). During traveling, the cow or calf was observed to blow approximately 74% of the time. The calf was inshore of the cow in 71% of the sightings.

A total of 157 sightings of cow/calf pairs were recorded as milling, with 17 pods (31%) engaging in this behavior (Table 42). Whales tended to congregate and mill in two areas: 1) just before crossing the embayment between Reef and Point Sal, and 2) offshore the Point Sal headland. On one occasion a cow/calf pair milled in the surf zone north of Mussel Point. Other surface activities and social behaviors observed during milling included 2 instances of breaching, 12 of rolling, and 6 of headlifting.

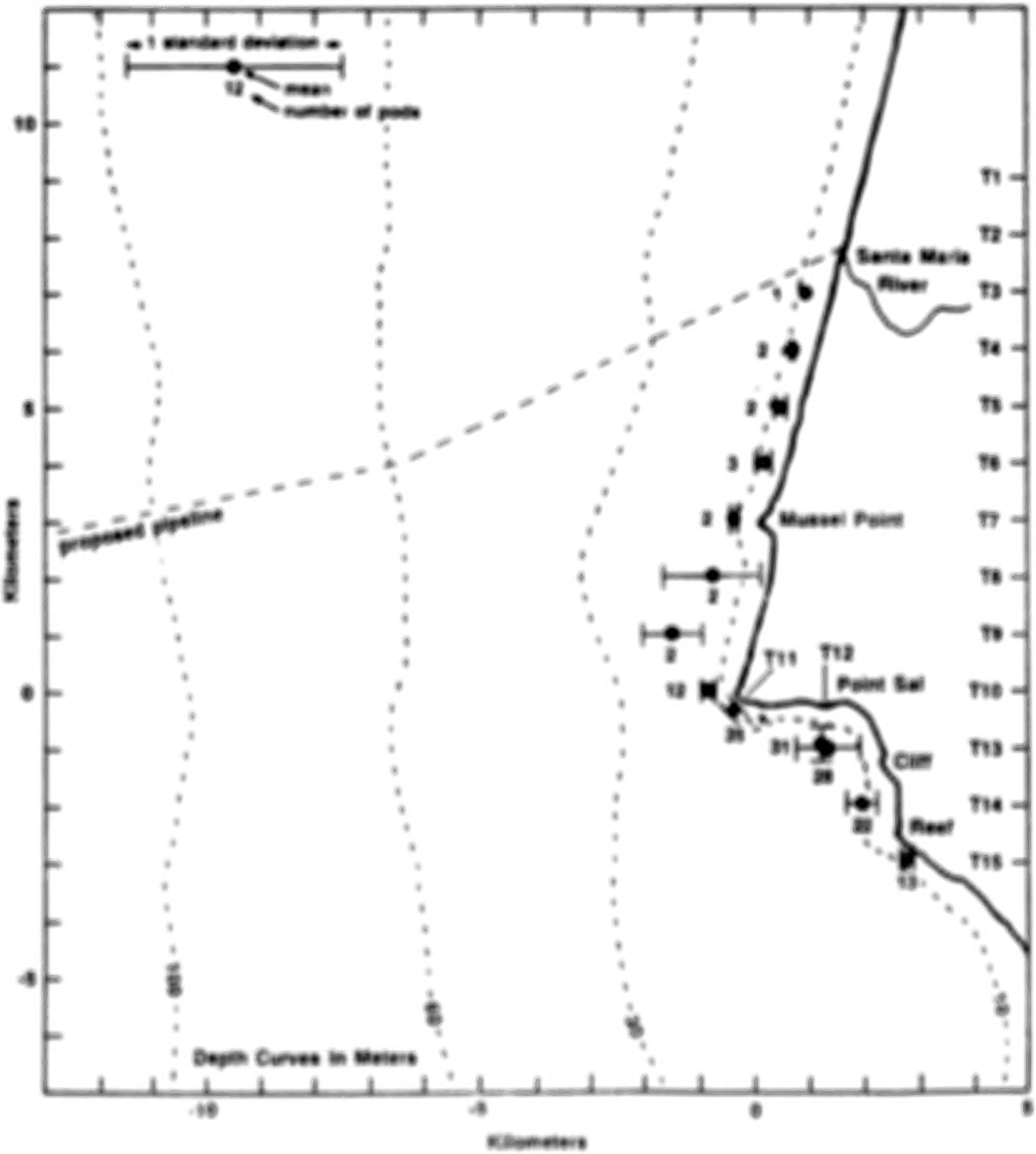

Figure 24. Mean migration corridor of Phase B gray whales in relation to the coast and bathymetry, shorebased observations, 1985 and 1986.

Table 39. Mean swimming speeds of Phase B gray whales by survey and pod size, shorebased observations, 1986 and 1988.

	Speeds (km/hr)					
	1986		1988		1986 and 1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
2	39	5.0 ± 1.3	4	5.3 ± 1.1	43	5.0 ± 1.3
3	1	3.4 -			1	3.4 -
4	8	4.9 ± 1.0			8	4.9 ± 1.0
6	1	5.2 -			1	5.2 -
Total	49	4.9 ± 1.3	4	5.3 ± 1.1	53	5.0 ± 1.3

Table 40. Mean dive duration times of Phase B gray whales by pod size and survey, shorebased observations, 1986 and 1988.

	Long Dives (1-10 min)			Short Dives (0-1.0 min)			All Dives (0-10 min)		
Pod Size	No. of Pods	No. of Dives	Mean ± S.D.	No. of Pods	No. of Dives	Mean ± S.D.	No. of Pods	No. of Dives	Mean ± S.D.
1986									
2	38	324	3.3 ± 0.5	35	230	0.6 ± 0.2	38	554	2.3 ± 0.9
3	1	22	2.7 -	1	62	0.3 -	1	84	0.9 -
4	9	118	3.2 ± 0.8	9	131	0.6 ± 0.2	9	249	1.9 ± 0.8
6	1	21	2.8	1	31	0.4 -	1	52	1.4 -
Total	49	485	3.2 ± 0.8	46	454	0.6 ± 0.2	49	939	2.2 ± 0.9
1988									
2	4	57	2.9 ± 0.6	4	50	0.4 ± 0.1	4	107	1.8 ± 0.4
1986 and 1988 Combined									
2	42	382	3.2 ± 0.8	39	280	0.5 ± 0.2	81	662	2.3 ± 0.8
3	1	22	2.7 -	1	62	0.3 -	2	84	0.9 -
4	9	118	3.0 ± 0.8	9	131	0.6 ± 0.2	18	249	1.9 ± 0.8
6	1	21	2.8 -	1	31	0.4 -	2	52	1.4 -
Total	53	543	3.2 ± 0.8	50	504	0.5 ± 0.2	103	1047	2.2 ± 0.8

Table 41. Respiration rates of Phase B gray whales, by pod size and survey, shorebased observations, 1986 and 1988.

	Respiration (Blows/hr)					
	1986		1988		1986-1988 Combined	
Pod Size	n	Mean ± S.D.	n	Mean ± S.D.	n	Mean ± S.D.
2	12	32.8 ± 15.7	4	19.9 ± 10.9	16	29.6 ± 15.7
3	1	24.4 -			1	24.4 -
4	3	27.9 ± 4.5			3	27.9 ± 4.5
6	1	30.6 -			1	30.6 -
Total	17	31.0 ± 13.7	4	19.9 ± 10.9	21	29.6 ± 14.0

The embayment between Point Sal and Cliff was utilized periodically by both recreational and commercial fishing vessels. Crab and gill net fishermen anchored in the lee of Point Sal during high winds. Merchant, commercial fishing, sport fishing, and recreational vessels were also observed offshore.

Of 84 vessels seen during 6 days of observation in 1986, 12 were in the embayment when gray whales were present. No obvious signs of vessel avoidance were noted and in only one instance did a pod appear to react to a vessel's presence. On 2 May, a commercial crabber was located approximately 1 km southeast of Point Sal. At 1312 hrs a cow/calf pair approached the vessel after milling in the state beach cove. At 1315 hrs, the vessel's engines were started and at 1316 hrs the pod dove and altered its course slightly to the side of the vessel. Shortly afterwards, the pod went around Lion Rock and moved upcoast while the vessel proceeded farther offshore. Three fishing vessels were observed during the 1988 Phase B studies; none was in the vicinity of the cow/calf pairs that were tracked between Point Sal and the Santa Maria River.

Aircraft in the area flying higher than 600 m were not tracked. Point Sal and the study area are within restricted military airspace which excludes commercial and private air traffic. Fixed-wing aircraft were observed occasionally taking off from and landing at Vandenberg Air Force Base approximately 8 km southeast of the study area. Helicopters appeared to be flying to oil platforms to the south but none passed over the study area.

OTHER ANIMALS OBSERVED

Other marine mammals were sighted during the aerial survey (Appendix D-33). These observations consisted of the following: 158 rafting California sea lions (*Zalophus californianus*); a minke whale (*Balaenoptera acutorostrata*); a humpback whale (*Megaptera novaeangliae*); 510 common dolphin (*Delphinus delphis*); at least 4,480 Pacific whitesided dolphin (*Lagenorhynchus obliquidens*); 76 bottlenose dolphin (*Tursiops truncatus*); and 20 Dall's porpoise (*Phocoenoides dalli*).

Table 42. A summary of gray whale behaviors observed in Phase B gray whales, shorebased observations, 1986 and 1988.

	Total	% Within Category
Number of Days	10	
Number of Pods	50	
Total Observation Time (hr)	74.2	
Traveling Activity		
Traveling	1060	87.1
Milling	157	12.9
Total	1217	100.0
Respiration		
Blows	486	47.0
Mother	123	11.9
Calf	93	9.0
Mother/Calf	61	5.9
Surfacing, No Blows Observed	272	26.3
Total	1035	100.0
Surface/Social Behaviors		
No Apparent Behavior	964	79.7
Breaching	2	0.2
Rolling	17	1.4
Headlift	6	0.5
Spyhop	1	0.1
Pod Splitting	9	0.7
Pods Joining	14	1.2
Tail Slap	0	0.0
Tail Lift	0	0.0
Calf Inside Mother	137	11.3
Calf Outside Mother	55	4.5
2 Calves/1 inside and the other outside	4	0.3
Vessel Avoidance	0	0.0
Total	1209	100.0
Diving Attitude		
Flukes Lifted	2	0.2
Flukes Not Lifted	1203	99.8
Total	1205	100.0

California sea lions were seen regularly from shore on Point Sal and Mussel Point, rafting or traveling to and from Lion Rock (Appendix E-45). Other non-cetaceans seen were 3 sightings of harbor seals (*Phoca vitulina*) and 4 sightings of solitary sea otters (*Enhydra lutris*). Cetacean sightings include 1 minke whale, 2 schools of common dolphin (200+ animals each), 2 killer whale (*Orcinus orca*) pods (15 to 18 animals each), 10 schools of bottlenose dolphin (85 animals), and an unidentified dolphin.

Gray whales appear to actively avoid killer whales *Orcinus orca*. On 25 April 1988, three killer whales (one large male, one small animal, and one juvenile), accompanied by over 100 seabirds, were observed feeding in a school of baitfish 3.2 km southwest of Point Sal. At 0850 hrs, these three individuals were joined by a pod of 10 to 12 more. For about 15 min both pods fed in the same area, although they did not mingle. At 0905 hrs, however, the smaller pod left and swam to the northeast; these three individuals were tracked for 9 min as they swam approximately 2 km offshore. As the smaller pod of killer whales was traveling offshore, a gray whale cow/calf pair was sighted in the surf zone swimming north between Point Sal and Mussel Point, just below the observation point. It appeared that the cow/calf pair was swimming at the surface, possibly to avoid detection by the killer whales.

More than 20 bottlenose dolphins were sighted traveling with a gray whale cow/calf pair on 27 April 1988. The bottlenose dolphins made frequent aerial displays, circled the gray whales, and both the bottlenose dolphins and the whales passed within 3 m of a group of surfers just south of the Santa Maria River.

LEVELS OF STATISTICAL DETECTABILITY

The primary purpose of this study was to provide a database from which to assess the effects of the presence of a drilling platform on gray whale migration and behavior. Therefore, it is important to determine the probability of detecting changes in whale behavior between pre- and post-installation conditions. For reference to subsequent surveys, it is possible to infer the minimum differences ("effects") that can be statistically detected using the present data set. Under the assumption of identical variances between the present study and the hypothesized future study, the analysis of variance can be utilized to back-calculate the minimum difference between means which will result in a significant test statistic. The minimum changes which could be detected by the present sampling techniques were determined by pooling the information collected from 1986 to 1988. It was assumed that the sampling effort in any post-platform study will be equal to or greater than the pre-platform effort.

In the shorebased analyses, the minimum detectible differences ($p>0.05$) ranged from 8.0 to 52.6, but most were between 15 and 40% of the means of the parameters measured (Table 43). For example, northbound Phase A animals move at approximately 5.1 km/hr and with the present database, the minimum change in speed that can be detected would be ±1.1 km/hr (22% of the mean). The shorebased study included breathing rates, speeds, and dive times, all of which can be measured with reasonable accuracy and thus are amenable to such statistical analysis.

The level of detectability is lower in the aerial survey data and, thus, large changes in parameter means would be required before differences could be detected (Table 44). This is partially due to limitations in the type of information that was collected and the spatial scale covered. The aerial study concentrated on the density and headings of whales and did not cover the entire area through which the whales traveled. Because of the nature of the aerial surveys, very large changes in the paths of the whales (i.e. on the scale of kilometers) will have to occur to be detected statistically.

The level of detectability can be improved by increasing the sample sizes in subsequent surveys, thereby decreasing the variance in the estimate of the parameter mean. The number of gray whales passing a shorebased sampling site on any particular day is relatively low. Therefore, to increase the sample size, an increase in the number of sampling days would be required, rather than an increased effort per day.

Table 43. Levels of detectability in shorebased survey data.

	Mean ± S.D.	N1	N2	D	% of Observed Mean
Southbound Migration					
Distance Offshore (km)	3.95 ± 2.73	51	51	1.95	49.37
Speed (km/hr)	7.22 ± 2.67	38	38	2.21	30.61
Respiration (blows/hr)	21.34 ± 8.70	40	40	7.00	32.80
Headings (° True)	161.23 ± 27.91	51	51	19.90	12.34
Dive Times:					
Short (min)	0.52 ± 0.18	38	38	0.15	28.59
Long (min)	4.03 ± 1.60	43	43	1.24	30.77
All (min)	2.47 ± 1.26	43	43	0.98	39.68
N1 = Sample size for MBC 1987 data. N2 = Projected sample size for treatment (operational) data. D = Difference ≥ baseline sample mean at p=0.95.					
Northbound Migration, Phase A					
Distance Offshore (km)	3.12 ± 2.34	126	126	1.07	34.29
Speed (km/hr)	5.13 ± 2.39	118	118	1.12	21.83
Respiration (blows/hr)	21.02 ± 9.01	93	93	4.76	22.65
Headings (° True)	330.53 ± 54.36	110	110	26.39	7.98
Dive Times:					
Short (min)	0.39 ± 0.15	86	86	0.08	20.51
Long (min)	3.96 ± 1.58	98	98	0.81	20.45
All (min)	2.43 ± 1.67	98	98	0.86	35.39
N1 = Sample size for MBC 1986-1988 data. N2 = Projected sample size for treatment (operational) data. D = Difference ≥ baseline sample mean at p=0.95.					
Northbound Migration, Phase B					
Distance Offshore (km)	0.41 ± 0.2	55	55	0.13	31.71
Speed (km/hr)	4.96 ± 1.27	53	53	0.89	17.94
Respiration (blows/hr)	29.57 ± 14.01	21	21	15.56	52.62
Dive Times:					
Short (min)	0.55 ± 0.2	50	50	0.14	25.45
Long (min)	3.19 ± 0.84	53	53	0.59	18.50
All (min)	2.19 ± 0.83	53	53	0.58	26.48
N1 = Sample size for MBC 1986,1987 data. N2 = Projected sample size for treatment (operational) data. D = Difference ≥ baseline sample mean at p=0.95.					

Table 44. Levels of detectability in aerial survey data.

	Mean ± S.D.	N1	N2	D	% of Observed Mean
Southbound Migration					
	Non-Cow/Calves				
Distance (km)	17.4 ± 6.1	25	25	6.21	35.69
Headings (° True)	181.2 ± 26.4	25	25	26.88	7.44
Density (#/km²)	0.027 ± 0.017	25	25	0.02	74.07
	Cow/Calves				
Distance (km)	17.2 ± 9.9	5	5	22.54	131.05
Headings (° True)	171 ± 11.5	5	5	26.18	7.27
Density (#/km²)	0.004 ± 0.003	5	5	0.01	250.00

N1 = Sample size for MBC 1987 data.
N2 = Projected sample size for treatment (operational) data.
D = Difference ≥ baseline sample mean at p=0.95.

	Mean ± S.D.	N1	N2	D	% of Observed Mean
Northbound Migration, Phase A					
Distance (km)	16.2 ± 7.6	97	97	3.93	24.26
Headings (° True)	2.8 ± 24.7	96	96	12.89	3.58
Density (#/km²)	0.014 ± 0.016	24	24	0.02	142.86

N1 = Sample size for MBC 1986-1988 data.
N2 = Projected sample size for treatment (operational) data.
D = Difference ≥ baseline sample mean at p=0.95.

	Mean ± S.D.	N1	N2	D	% of Observed Mean
Northbound Migration, Phase B					
Distance (km)	8.9 ± 5.1	10	10	8.21	92.25
Headings (° True)	356.6 ± 12.9	10	10	20.77	5.77
Density (#/km²)	0.001 ± 0.01	24	24	0.001	100.00

N1 = Sample size for MBC 1986,1987 data.
N2 = Projected sample size for treatment (operational) data.
D = Difference ≥ baseline sample mean at p=0.95.

DISCUSSION

SOUTHBOUND MIGRATION

ABUNDANCE

Thirty pods and 99 individual gray whales were observed during aerial surveys of southbound individuals in January 1987. Nearly 95% of the animals traveled in groups of two or more animals. Shorebased observers sighted 70 pods and 131 whales. Seventy-six percent of the individuals were in pods of two or more. The rate of sightings, which ranged from 1.7 to 6.0 whales/hr, averaged 4.2 whale/hr, and was similar to the 3 to 6 whales/hr reported by Behrens (pers. comm.) at Diablo Canyon, 35 km northwest of Point Sal during the same period.

The rate of sightings at Point Sal and Diablo Canyon were both lower than those reported at Yankee Point and Granite Canyon (Monterey County) in previous years. Counts as high as 52 whales/hr were recorded during 1981 (Reilly *et al.* 1983) and 22.8 whales/hr on 20 January 1986 (Breiwick and Dahlheim 1986). These differences may be a function of sighting technique, sampling effort, and the timing of the sampling effort. The coastal physiography and the width of the migration corridor are also different and may account for the differences.

The average density of non-cow/calf whales observed off Point Sal was 0.025 whales/km^2. Although less than that reported for channels and islands nearshore in southern California (Table 45; Jones and Swartz 1987a,b), this value is quite similar to those densities reported for non-cow/calf whales in open water. The average density of cow/calf whales off Point Sal was 0.004 whales/km^2. This is comparable to densities reported for cow/calf whales by Jones and Swartz (1987a,b) for open water in the Channel Islands National Marine Sanctuary (CINMS), and only slightly lower than the values reported for the channels between islands. The densities reported by Jones and Swartz for cow/calf pairs in the nearshore areas of the CINMS was three to six times greater than those observed in the present study. Jones and Swartz (1987a) suggest that the concentrations of cow/calf pairs in the CINMS waters could indicate that the offshore islands are used as a resting point along the migration, prior to beginning the next leg of the journey. Alternatively, they hypothesize that the CINMS may be a wintering area for cow/calf pairs which do not make the entire migration to the calving grounds along the Baja California Peninsula.

Table 45. Densities of non-cow/calf and cow/calf whales observed within the Channel Island National Marine Sanctuary in 1986 and 1987.

Observation Area	1986	1987
Non-Cow/Calf Number/km^2		
Channels	0.101	0.071
Islands	0.076	0.105
Open Water	0.018	0.026
Cow/Calf Number/km^2		
Channels	0.009	0.006
Islands	0.012	0.025
Open Water	0.000	0.010

Source: Jones and Swartz 1987a,b

Generally, cow/calf pairs have been observed only during the northbound migration, after birthing in the lagoons of Baja California. However, during the present study, eight southbound cow/calf pairs were observed in January 1987, five in aerial and three in shorebased surveys. Southbound cow/calves have been recorded as early as the mid-1950s (Yochem *et al.* 1986). Maime *et al.* (1983a) observed 7 southbound cow/calf pairs passing their Soberanes study site in January 1983 and 15 pairs in January 1984 (Maime *et al.* 1984). In 1986, 15 cow/calf pairs were seen traveling south offshore Granite Canyon (Breiwick and Dahlheim, unpubl.). Jones and Swartz (1987a,b) sighted 19 calves in the waters of the CINMS in January 1986 and 7 in January 1987. Subsequent to the cow/calf sightings in the Channel Islands and the Santa Maria Basin, three southbound calves were sighted in the Southern California Bight (SRA 1988).

It is not clear if the increased frequency of sightings of southbound cow/calf pairs is simply due to increased observation effort, or to other causes. There is no evidence that the calves born during the southbound migration are born prematurely, as the birthing period generally occurs between late December and mid February (Rice and Wolman 1971).

MIGRATORY CORRIDORS

Gray whales generally travel close to shore during the southbound migration (Table 46). In the vicinity of embayments and offshore islands, they may travel further offshore moving from headland to headland. In areas such as the Southern California Bight (Dohl *et al.* 1981b, SRA 1988), San Luis Bay, Monterey Bay and the Farallon Islands (Dohl *et al.* 1983a) gray whales characteristically travel farther offshore.

The mechanisms that affect the nearshore-offshore distribution of gray whales are not clear. Possible factors include distance from shore, water depth, currents, population size, availability of food, and the

Table 44. Summary of migration corridors, northbound and southbound.

Location	Maximum Distance From Shore	% of Census	Reference
	Southbound Migration		
Newport, OR (Yaquina Head)	3.2 - 4.8 km	68	Herzing & Mate 1984
No. CA (along coast)	1.8 km	-	Dohl et al. 1981
(San Francisco	46 km	-	Dohl et al. 1981
(Channel Islands)	83 km	-	Dohl et al. 1981
Monterey (Yankee Pt.)	1.5 km	73	Rice & Wolman 1971
Monterey	1.9 km	95	
Monterey	1.6 km	94	Sund & O'Connor 1974
Monterey (Yankee Pt.)	1.6 km	40	Reilly 1981
	5 km	95	
Monterey (Soberanes Pt.)	1 - 4 km	-	Malme et al. 1983b
Point Sal	0.2 - 31.5 km	-	MBC, this study
Channel Islands	200 km	-	Rice & Wolman 1971
San Diego (Pt. Loma)	9.3 km	41	Rice & Wolman 1971
	195 km	100	
	Northbound Migration		
Monterey (Piedras Blancas)	10 - 200 m	13 Phase A	Poole 1984
	0.2 - 0.8 km	20	
	0.8 - 3.2 km	67	
	10 - 200 m	96-99 Phase B	
Monterey (Soberanes Pt.)	10 - 500 m	Phase B	Malme et al. 1983b
Pt. Buchon to Pt. Estero (Morro Bay)	12 km	Phase A	Poole 1984
	10 - 400 km	Phase B	
Purisima Pt.	40.7 km	Phase A	MBC, this study
Pt. Sal	0.1 - 15 km	Phase B	MBC, this study
Newport, OR (Yaquina Head)	1.6 - 3.2 km	50 Phase A	Herzing & Mate 1984
	0 - 0.8 km	97 Phase B	

Source: Bolt Beranek and Newman Laboratories, Inc. 1986 amount of human disturbances. Most of these factors co-vary along the entire migration route, making it difficult to separate their effects.

Because gray whales are coastal migrants, they may rely visually on coastal features such as mountains and promontories to judge their distance from shore (Pike 1962). Norris and Prescott (1961) and Pike (1962) suggested that gray whales use water depth for orientation, remaining for the most part between the 100 and 200 m isobaths. Although disputed, ocean currents have also been suggested as an important navigational aid (Gilmore 1960, Nasu 1974). During the northward migration, the sublittoral food resources (which may be necessary for the cows to replenish fat reserves) may be an important factor. For instance, cows may stay in water depths which are sufficiently shallow for benthic feeding (Braham 1984, Poole 1984).

Aerial Surveys

During aerial surveys in the present study, southbound gray whales were seen as far as 32 km offshore Point Sal, over the inner edge of the Santa Maria Basin, but were most common at 10 to 24 km from shore. Seventy-three percent of whales were between 10 to 24 km from shore. Proposed Platform Julius, which is to be 15.5 km offshore Point Sal, would be located 1 to 3 km east of the center of the southbound migratory corridor.

Ninety-four percent of the southbound whales observed were in pods of two or more. This apparent tendency to travel in groups may reflect the timing of the surveys. Rice and Wolman (1971) reported that single whales were more common early in the southbound migration, while groups were more common from the middle through the end of the migration.

Non-cow/calf pods had a mean heading of 181°T at an average distance offshore of 17.4 km. The corridor was wider (toward shore) in the vicinity of San Luis Bay. Cow/calf groups were scattered between the shore and the seaward limit of the study area, 32 km offshore. Their mean heading was 171°T and their average distance from shore was 17.2 km.

Other aerial surveys have investigated the migratory corridor of the gray whale. Sund and O'Connor (1974) surveyed distances up to 40.2 km offshore Monterey. All sightings were within 11.3 km of the shore and 94% were within 1.6 km. Reilly *et al.* (1980) observed 40% of the whales within 1.6 km of shore at Monterey and significant numbers were 1.6 to 4.5 km from shore. Dohl *et al.* (1981b) observed that 97% of all gray whales between Point Arguello and Monterey were within 2.8 km of shore and no whales were seen further than 4.6 km from shore. During three years of aerial surveys off northern and central California, 93.5% of all gray whales observed were within 9.2 km of shore except offshore embayments and bights (Dohl *et al.* 1983).

The migration corridor at Point Sal is markedly different from that offshore Granite Canyon, probably as a result of differences in the coastal physiography. Most of the whales observed in this study were 10 to 32 km offshore, with only 10% of all sightings within 10 km of shore. By contrast, 40% of the whales seen in aerial studies offshore Yankee Point were within 4 km of shore (Reilly *et al.* 1980). However, it should be noted that the region within 3.2 km of shore was not surveyed by air in the present study.

This difference in corridor width may be related to the width of the mainland shelf where the studies were conducted. Off Point Sal the mainland shelf extends 24 km offshore and whales were widely dispersed. Off Yankee Point and Granite Canyon, the shelf extends about 8 km offshore and most whales traveled closer to shore. These relationships suggest that gray whales may orient to water depth instead of horizontal distance to landmarks on shore. Nearly 85% of the whales in the present study were over shelf waters (0 to 200 m) and only 15% were over the continental slope (200 to 1000 m). Of those gray whales over the shelf, 73% were traveling above the mainland shelfbreak, in water depths of 100 to 200 m, and the remainder were inshore of the 100 m isobath.

Mean pod size increased with distance offshore; the abundance of pods of three or more individuals increased with distance from shore. Pods of one and two were all within 24 km of shore. Spatial segregation by pod size has been noted in previous studies of the southbound migration and it has been generally found that larger pods travel farther from shore (Reilly *et al.* 1983, Behrens and Shafter 1985, Breiwick and Dahlheim 1986). However, this pattern may also vary geographically. In the Channel Islands National Marine Sanctuary smaller groups of gray whales occurred farther offshore than larger groups (Jones and Swartz 1987a,b). It was suggested that the whales aggregate near shore because the islands are their first landfall after having left the coast near Point Conception to traverse the Santa Barbara Channel.

Shorebased Surveys

In the shorebased surveys, most sightings were within 5 to 6 km of shore, although during periods of exceptional visibility, whales were seen as far as 10 km offshore. When these shorebased data are compared to those from Granite Canyon and Yankee Point (Breiwick and Dahlheim 1986), it is apparent that the southbound migratory corridor off Point Sal is wider. Seventy-eight percent of all whales at Point Sal were within 6 km of shore; at Granite Canyon, 81% of the animals were within 2.4 km of the shore.

Comparisons between the distribution of gray whales at Granite Canyon and Point Sal may also be affected by differences in the coastal configuration, sample sizes (131 whales at Point Sal versus 5,314 at Granite Canyon), methods (theodolite at Point Sal and reticulated binoculars at Granite Canyon), and the height of the observation site (117.0 m at Point Sal and 25.6 m at Granite Canyon).

Jones and Swartz (1987a,b) noted that almost two-thirds of the cow/calf pairs sighted in the Channel Islands National Marine Sanctuary during the southward migration were in depths less than 55 m.

There was no evidence that southbound cow/calf pairs in the present study traveled exclusively in shallow water. The three pods which were observed from shore were within 3 km of shore in water less than 30 m deep. The five pods seen in aerial surveys were in water depths that ranged from 30 to 400 m. This suggests that cows which give birth while southbound do not necessarily follow the shoreline as do northbound cows.

The mean pod size (1.9 whales) in the nearshore portion of the Santa Maria Basin was smaller than in the more offshore aerial survey area, 3.3 whales/pod (Table 47). Gray whales traveled in similar-sized pods while passing Diablo and Granite Canyons. Observers at Diablo Canyon recorded mean pod sizes of 1.4 to 2.3 whales/pod between 1984 and 1986 (Behrens 1987), while Breiwick and Dahlheim (1986) reported mean pod sizes of 2.4 whales/pod in 1984-1985 and 2.2 in 1985-1986.

SWIMMING SPEEDS

The average swimming speed of southbound non-cow/calves off Point Sal was 7.2 km/hr, which is typical of speeds reported from shorebased and radio-tagging studies elsewhere along the central California coast (Table 48). Southbound cow/calves, on the other hand, traveled at a rate of 5.0 km/hr, nearly 2.2 km slower. Maime *et al.* (1983a) reported that southbound gray whales traveled past Soberanes Point at speeds of 5 to 10 km/hr during the 1983 migration (Table 48). Southbound whales were radio-tagged near Monterey to determine differences in day and night travel rates (Swartz and Harvey 1985). A single whale averaged 6.9 km/hr during daylight. Averages at night were 5.6 and 6.3 km/hr for two whales, but ranged as high as 7.0 km/hr over short segments of the track.

Other average speeds that have been measured offshore central California (Monterey) range from 6.2 to 9.3 km/hr (Rice and Wolman 1971, Maime *et al.* 1983a; Table 48). Near the Channel Islands National Marine Sanctuary radio-tagged whales had an average day swimming speed of 6.0 km/hr and a night rate of 6.2 km/hr (Jones and Swartz 1987a).

Table 47. Summary of southbound shorebased and aerial surveys data, January 1987.

Parameter	Shore-Based	Aerial
Total Observation Time (hrs)	31.2	11.4
Total Track Time (hrs)	19.3	-
Number of Pods Tracked	70	30
Number of Cow/Calf pairs	3	5
Number of Whales	131	99
Mean Pod Size	1.9	3.3
Mean Distance from Shore (km)		
Non-Cow/Calves		
Mean	4.0	17.4
Std. Dev.	3	6.5
N	51.0	25
Range	0.2-10.3	4.5-31.5
Cow/Calves		
Mean	1.8	17.2
Std.Dev.	0.2	9.9
N	3	5
Range	1.6-3.0	5.5-31.0
All Pods		
Mean	3.8	17.4
Std.Dev.	2.7	6.5
N	54	30
Range	0.2-10.3	4.5-31.5
Mean Course Heading (° True)		
Non-Cow/Calves		
Mean	161.6	181.2
Std.Dev.	26.9	26.4
N	51	25
Range	76.9-216.2	156-216
Cow/Calves		
Mean	131.8	171
Std.Dev.	25.2	11.5
N	3.0	5
Range	98.1-149.3	156-181
All Pods		
Mean	160.0	179.2
Std.Dev.	27.6	14.2
N	54	30
Range	76.9-216.2	156-216
Mean Traveling Speed (km/hr)		
Non-Cow/Calves		
Mean	7.2	-
Std.Dev.	2.7	-
N	38	-
Range	2.3-16.6	-
Cow/Calves		
Mean	5.0	-
Std.Dev.	2.0	-
N	3	-
Range	2.1-6.4	-
All Pods		
Mean	7.1	-
Std.Dev.	2.7	-
N	41	-
Range	2.1-16.6	-
Mean Dive Duration (min)		
Dives <1.0 min		
Non-Cow/Calves		
Mean	0.5	-
Std.Dev.	0.2	-
N	38	-
Dives <1.0 min (Cont)		
Cow/Calves		
Mean	0.5	-
Std.Dev.	0.0	-
N	3	-
Dives 1.0-10.0 min		
Non-Cow/Calves		
Mean	4.0	-
Std.Dev.	1.6	-
N	43	-
Cow/Calves		
Mean	3.2	-
Std.Dev.	0.7	-
N	3	-
Dives 0-10 min		
Non-Cow/Calves		
Mean	2.5	-
Std.Dev.	1.3	-
N	43	-
Cow/Calves		
Mean	2.1	-
Std.Dev.	0.6	-
N	3	-
Mean Respiration Rate (blows/hr)		
Non-Cow/Calves		
Mean	21.3	-
Std.Dev.	8.7	-
N	40	-
Range	8.8-44.2	-
Cow/Calves		
Mean	18.5	-
Std.Dev.	7.0	-
N	3.0	-
Range	10.2-27.3	-
All Pods		
Mean	21.1	-
Std.Dev.	8.6	-
N	43.0	-
Range	8.8-44.2	-
Mean Density (N/km^2)		
Non-Cow/Calves		
Mean	-	0.027
Std.Dev.	-	0.017
# Blocks	-	24
# Pods (N)	-	25
# Whales	-	86
Range	-	0.005-0.055
Cow/Calves		
Mean	-	0.004
Std.Dev.	-	0.003
# Blocks	-	24
# Pods (n)	-	5
# Whales	-	13
Range	-	0.000-0.008

Table 48. Comparative data for gray whale swimming speeds between Unimak Pass, Alaska and Baja California.

Location	Southbound (km/hr)	Northbound (km/hr)	Phase A (km/hr)	Phase B (km/hr)	Reference
Unimak Pass to San Diego	4.3				Rugh & Braham 1979
Alaska to Monterey	5.2	3.7			Pike 1962
British Columbia to San Diego	6.7	3.8			Gilmore 1960, Pike 1962
Oregon to Unimak Pass		3.8			Mate & Harvey 1984
CA, Oregon, B.C. Coasts	7.41				Pike 1962
Cape Flattery, WA		2.8-3.7			Pike 1962
Yaquina Head, OR			5.0		Herzing & Mate 1984
Monterey	7.5 (5-10)			5.2	Malme et al. 1983a
Monterey	7.4-9.3				Rice & Wolman 1971
Monterey		3.7-4.6			Rice & Wolman 1971
Monterey	6.19				Breiwick & Dahlheim 1986
Point Sal	7.2		5.1	5.0	MBC, this study
La Jolla to San Diego	8.5 (4.4-12)				Wyrick 1954
San Diego (Pt. Loma)	8.5				Pike 1962
San Diego (Pt. Loma)	7.2				Sumich 1983
San Diego	10.2				Cummings et al. 1968
San Diego	7.2				Sumich 1983
San Diego	2.8				Wyrick 1954
San Diego		2.8			Leatherwood 1974a
San Diego	day-7.7, night-7.1				Rice & Wolman 1971
Single Tagged Whales					
Oregon to Unimak Pass AK		5.3			Mate & Harvey 1984
Oregon Coast		4.1			Mate & Harvey 1984
San Diego to Coos Bay, OR		3.3			Mate & Harvey 1984
Monterey	day-6.63, night-6.57				Swartz & Harvey 1985
Monterey	day-5.98, night-6.10				Swartz & Harvey 1985
Monterey	5-10				Malme et al. 1983a
Central CA to Central Oregon		2.8			Mate & Harvey 1984
Monterey to San Diego	8.7				Reilly 1981
Channel Islands	day-5.59, night-6.30				Jones & Swartz 1987a
Baja to San Diego		1.4			Mate & Harvey 1984

Sources: Malme et al. 1984; Jones and Swartz 1987a

DIVE DURATION

Previous observations have indicated that the general diving pattern of gray whales is a series of short dives less than 1 min long, usually accompanied by exhalations, which is followed by a longer, deeper dive (Table 49). However, this pattern apparently varies with a number of factors. Morejohn (1968), Malme *et al.* (1983a), Richardson *et al.* (1983), Sumich (1983), and Swartz and Harvey (1985) have suggested that gray whales' dive-exhalation patterns vary according to the type of activity (i.e. feeding, courtship, resting, and day or night traveling), group type, and the level of stress.

Harvey and Mate (1984) described four gray whale dive patterns: 1) regular, long dives of greater than 1 min; 2) regular, short dives of less than 1 min; and 3) clumped dives, a combination consisting of a long dive of greater than 1 min followed by 2 to 6 dives of less than 1 min each; and 4) irregular or unpatterned dives. Murison *et al.* (1984) and Harvey and Mate (1984) noted that the pattern may be different during nonmigratory periods than during migrations.

Table 49. Dive times recorded in the present and other recent studies.

Location	Mean Dive Duration	Reference
Bering Sea	2.98 to 3.53 min 3.35 min	Wursig et al. 1986
Pt. Sur-Piedras Blancas	day: 2.8 min night: 2.9 min night: 5.1 min	Swartz and Harvey 1985
Point Sal	Southbound Singles: <1.0 min; mean=0.5 min 1-10 min; mean=4.6 min all dives, mean=3.1 min Groups of 2 or more: <1.0 min; mean=0.5 min 1-10 min; mean=3.6 min all dives, mean=1.9 min Northbound Phase A Singles: <1.0 min; mean=0.4 1-10 min; mean=4.4 min all dives, mean=3.1 min Groups of 2 or more: <1.0 min; mean=0.4 1-10 min; mean=3.6 min all dives, mean=1.9 min Northbound Phase B Single cow/calf pairs: <1.0 min; mean=0.5 min 1-10 min; mean=3.2 min all dives, mean=2.3 min Groups of 2 or more pairs: <1.0 min; mean=0.6 min 1-10 min; mean=3.0 min all dives, mean=1.8 min	MBC, this study
Channel Islands	<1 min 46% mean=0.5 min (0.07-1.0 min) >1min 53% Mean=3.1 min (1-28) min	Jones and Swartz 1987a
San Diego	67% <1 min 33% >2 min faster whales: long dive=3 min slower whales: long dive=4 min	Sumich 1983
Baja Calving Lagoons	mean=1.6 min (all dives) 51% <1 min 99% <6 min mean dives >1 min; mean=2.7 min	Harvey and Mate 1984

Jones and Swartz (1987a) measured average dive durations of 3.1 min for long dives and 0.5 min on short dives for radio-tagged individuals traveling in pods near the Channel Islands. Only a single radio-tagged whale exhibited lower and more variable dive times than did whales traveling with other whales. This compares favorably with the results of the present study. The dive duration of individuals in groups was also shorter than that observed in individuals traveling alone.

RESPIRATION RATES

The respiration rates of gray whales were not significantly different with regard to pod size. The mean respiration rate of southbound, non-cow/calf pods was 21.3 blows/hr., and of cow/calf pairs 18.5 blows/hr. By comparison, Sumich (1983) calculated the mean blow rate of 74 whales passing Point Loma at 43.2 blows/hr. Swartz and Harvey (1985) estimated that 95% of surfacings are accompanied by a blow. They utilized surfacing rates to estimate respiration rates, applying this 45% correction to the surfacing rate. Radio-tagged whales traveling between Monterey and Point Piedras Blancas were estimated to blow at rates of 15.9 blows/hr during the day, and between 23.9 and 29.2 blows/hr at night.

BEHAVIOR

Most gray whales traveled southward past Point Sal without interruption. Occasionally surface displays such as breaches, headlifts, rolling, joining and splitting were observed. These displays were made by singles or pods of two animals, usually far offshore. During the 1983 southbound migration off Soberanes Point, Malme *et al.* (1983a, 1984) observed similar behaviors as well as vertical flukes, spy-hopping, and underwater bubble bursts. These displays were seen in groups of three or more whales.

NORTHBOUND MIGRATION

After birthing and breeding in the lagoons of Baja California in the early spring, gray whales begin their northward migration to the Arctic. On the basis of gonadal analyses, Rice and Wolman (1971) determined that the northward migration consisted of the following sequence: 1) newly pregnant females; 2) adult males; 3) recently ovulated females; 4) immature females; 5) immature males; and 6) females with calves. Along the California and Oregon coasts, the northward migration has been shown to consist of two pulses (Poole 1984, Herzing and Mate 1984). The first pulse (Phase A of Poole 1984) consists of non-cow/calf pods, these are offshore central California between February and early April. Phase A is a composite of the first five of Rice and Wolman's (1971) categories. The second pulse (Phase B) consists cow/calf pairs, these pass central California from late March to the end of May. Cow/calf pairs generally travel very close to shore.

The two phases are not always distinct (Behrens and Shaffer 1985; Behrens, pers. comm.) and the dates that the first and the last whales are seen varies from year to year. Poole (1984) also noted that near Piedras Blancas, the Phase A migration varied spatially and temporally. Because of the different characteristics of these phases they are discussed separately.

PHASE A MIGRATION

Aerial Surveys

Totals of 95 Phase A pods and 254 whales were sighted in the study area during aerial surveys in 1987 and 1988. Ninety percent of these individuals were traveling in groups of two or more. The density of Phase A animals averaged 0.014 whales/km^2 (Table 50); it was greater during early Phase A (March) than late Phase A (May).

Phase A whales were seen as close to shore as 0.5 km and as distant as 33 km offshore Purisima Point. During the 1987 surveys the average distance offshore was 15.1 km; in 1988 this distance was 13.3 km. Combined 1987 and 1988 data indicate that 86.6% of the observed whales were within 19 km of shore. Phase A whales crossing the Santa Maria Basin toward Point San Luis during the present study were farther offshore than reported by other investigators along central California and the Oregon Coast. This probably results from the tendency of gray whales to travel from headland to headland.

Table 50. Summary of northbound Phase A and B data, April 1986 to April 1988.

	Phase A		Phase B (Cow/Calf)	
Parameter	Shore-based	Aerial	Shore-Based	Aerial
Total Observation Time (hrs)	169.6	40.5	74.2	40.5
Total Track Time (hrs)	44.8	-	34.2	-
Number of Pods Tracked	167	95	50	9
Number of Whales	260	254	111	23
Mean Pod Size	1.6	2.7	2.2	2.6
Mean Distance From Shore (km)				
Mean	3.1	14.1	0.4	8.0
Std.Dev.	2.4	6.2	0.2	4.2
N	126	9.5	55	9
Range	0.3-11.6	2.5-33.0	0.2-1.2	2.0-15.0
Mean Course Heading (° True)				
Mean	325.0	2.8	-	355.4
Std.Dev.	47.6	24.7	-	13.7
N	109	95	-	8
Mean Traveling Speed (km/hr)				
Mean	5.1	-	5.0	-
Std.Dev.	2.4	-	1.3	-
N	118	-	53	-
Range	0.1-14.7	-	1.8-7.7	-
Mean Dive Duration (dives <1.0 min)				
Mean	0.4	-	0.5	-
Std.Dev.	0.2	-	0.2	-
N	86	-	50	-
(dives 1.0-10.0 min)				
Mean	4.0	-	3.2	-
Std.Dev.	1.6	-	0.8	-
N	98	-	53	-
(dives 0-10 min)				
Mean	2.4	-	2.2	-
Std.Dev.	1.7	-	0.8	-
N	98	-	53	-
Mean Respiration Rate (blows/hr)				
Mean	21.2	-	29.6	-
Std.Dev.	9.0	-	14	-
N	93	-	21	-
Range	1.6-54.5	-	9.9-76.9	-
Mean Density (#/km^2)				
Mean	-	0.014	-	0.001
Std.Dev.	-	0.016	-	0.01
# Blocks	-	24	-	24
# Pods (N)	-	95	-	9
# Whales	-	254	-	23

Poole (1984) reported that during aerial surveys between Point Buchon and Point Estero, Phase A whales were always within 12.0 km of shore, crossing in a straight line between the two headlands. Off Piedras Blancas, whales were observed up to 5.2 km from shore. Along the Oregon Coast, Herzing and Mate (1984) reported that whales traveled as much as 24 km offshore but that the majority were within 1.6 to 3.2 km from shore.

In the present study the mean number of individuals per pod increased with distance offshore. A similar trend of increasing pod size offshore has been reported by Poole (1984) off Estero Point, and Herzing and Mate (1984) off Yaquina Head, Oregon.

Shorebased Surveys

Abundance. The abundance, behaviors, and migratory corridors of Phase A whales in this study were assessed on the basis of 123 pods (a total of 260 whales) which were observed from shore at Point Sal during 1987 and 1988. Sighting rates were much greater in March than in April and May, reflecting the pulsed nature of the migration.

Observers from Pacific Gas and Electric facilities at Diablo Canyon maintain a watch on gray whales during the migration season. During same day observations in 1987 and 1988, the rate of sightings at Point Sal and Diablo Canyon were markedly different. On 26 March 1987, Point Sal observers sighted 2.2 whales/hr as compared to 9.5 whales/hr at Diablo Canyon (Behrens, pers. comm.). On 11 March 1988, observers at Point Sal sighted [illegible] whales/hr compared to 12.7 whales/hr at Diablo Canyon.

Migratory Corridors. In 1987 and 1988 the inshore component of Phase A was tracked between Point Sal and the Santa Maria River. The results indicated that the northbound corridor is as wide as the southbound corridor but the whales were closer to shore. Phase A whales were sighted from the surf zone up to 11.6 km offshore. Nearly 75% of the animals were within 5 km of shore. As was seen during aerial surveys, the corridor of this nearshore portion of Phase A migrants was farther from shore than that reported at other sites.

The mean heading of whales observed in the shorebased survey varied with their location along the coastline and their distance from shore. Some whales followed the coastline closely, and approached Point Sal from the east (Point Sal Cove), some from the south. Others followed a more direct, headland to headland path, and by-passed Point Sal altogether, traveling well offshore.

At Point Sal, whales passed close to shore, within the 10 m isobath, and as they moved across open water toward Point San Luis they passed over increasingly deeper waters. A portion of the migrants stayed nearshore, and traveled just beyond the surf between Point Sal and the Santa Maria River before making their offshore turn towards Point San Luis.

Speed. At Point Sal Phase A whales traveled at an average speed of 5.1 km/hr, which is about 75% of the speed of southbound whales (Table 50). Pike (1962) and Mate and Harvey (1984) both noted that northbound whales travel about half as fast as southbound whales. Speeds of northbound whales vary along the migration route; speeds are slower off Baja California and southern/central California, and accelerate as the whales progress into the northern part of their range (Mate and Harvey 1984).

Behavior. During the Phase A migration, behavior other than traveling was characterized by moderate amounts of nondirected movement, such as swimming slowly ("lollygagging"), and "drifting" with the current, all of which resulted in an extremely wide range of course headings. Pods of three or more animals frequently engaged in a variety of body-part displays. This playful behavior or "frolicking" (M. Poole, pers. comm. 1987) resembled courtship and sexual behavior, although no indication of copulation was observed. Sexual activity during the northward migration has been observed off Pecho Rock, San Luis Obispo County (Wilson and Behrens 1982). Baldridge (1974) also described sexual behavior of gray whales during the northward migration near Monterey.

PHASE B MIGRATION

Shorebased Surveys

Abundance. In 1986, the mean sighting rate (2.6 whales/hr) and the peak rate of whales passing Point Sal (4.6 whales/hr) compared favorably to the rate (approximately 3 whales/hr) observed during the first week in May at Diablo Canyon (Behrens 1987). That these rates were similar may reflect the fact that most cow/calf pairs stay closer to shore than non-cow/calf whales. Field observers have less difficulty in tracking cow/calf pairs close to shore than whales farther offshore and, thus, the counts are likely to be more reliable.

During the Phase B migration of May 1986, a trio of a cow and two calves was observed from shore. Because of the unusual nature of this observation (the energy demands of two calves would severely burden the cow) and the fact that such occurrences have not been previously reported in the literature, the circumstances surrounding the observations were reviewed; no errors in observation or recording were identified. The distance and time the whales were tracked were recalculated and it was determined that the pod was tracked for over an hour, beginning 4 km and ending 0.3 km from Point Sal where the animals were in full view of the observers. The two calves were usually seaward of the cow, but in a few instances shoreward of her; by size and by behavior the two small animals were no different than others seen during the course of the field survey. Based on the review and conversations with other students of gray whale biology, the sighting at Point Sal was regarded as a probable sighting of a cow with two calves, which was accurate and valid at least while within the study area. This raises the question of the relationship of the female and two calves and there are three possible explanations: 1) that the cow gave birth to twins; 2) that one of the calves was the cow's own, the other a temporary or permanent adoption of an orphaned or abandoned calf; and 3) one calf represented a small yearling traveling with a young-of-the-year calf and the mother. Although not reported in the literature, on one occasion at Point Piedras Blancas, field observers noted two calves with a single female, and it was the observer's impression that the two calves had very similar, if not identical, markings (Poole, pers. comm.).

Migratory Corridor. Occasionally early Phase B animals are sighted over deep waters, traveling within the typical Phase A corridor. As the migration progresses, the distribution by water depth shifts and all animals occurr in water depths less than 100 m.

Nine cow/calf pairs were seen over waters between 30 and 200 m deep during aerial surveys; while shorebased observers tracked 50 cow/calf groups. All of these individuals were within 2 km of shore, following the coastline at water depths of less than 30 m. The Phase B migration corridor south of Point Sal and north to the Santa Maria River was narrow. Cow/calf pairs ranged from 20 m to 1.2 km offshore, the average distance offshore was 400 m, and 92% were within 700 m of shore. Most of the cow/calf pairs followed the Point Sal shoreline very closely; some cut across the embayment from Reef to Lion Rock while a few followed a path farther from shore, within 1.2 km of the shoreline. Most of the cow/calf pairs avoided swimming between the shoreline and Lion Rock; they went outside of Lion Rock and then around Point Sal and Mussel Point toward the Santa Maria River.

The distribution of Phase B whales at Point Sal was very similar to that at Point Piedras Blancas (Poole 1984) and at Yaquina Head, Oregon (Herzing and Mate 1984). At Point Piedras Blancas, approximately 99% of the whales in 1981 and 90% in 1982 were between 10 and 200 m from shore (Poole 1984). Along the Oregon coast the average distance offshore was 400 m and 90% were within 800 m of shore (Herzing and Mate 1984). In aerial surveys, Poole (1984) noted that cow/calf pairs rarely take an offshore route. Along a 94 km stretch of coast between Point Estero and Point Piedras Blancas, 76% of the individuals were sighted within 25 to 400 m of shore. The numbers of cow/calf pairs traveling offshore the central California coast is in "the tenths of one percent" (T. Dohl in Poole 1984).

Speculation as to why the migration is so nearshore has centered on 1) the cows' need to feed, at least occasionally, to maintain enough energy to nurse their calves (Sumich 1982), and 2) the protection that the nearshore provides against predators such as killer whales (Poole 1984). Cows with newborn calves have different energetic needs and survival problems than do other northbound gray whales (Poole 1984). As a result they modify their migration behavior by staying closer to shore for possible protection and feeding purposes; differences in diving and respiration patterns might also be expected, to allow the cow to respond to the needs of her calf.

Swimming Speed. At Point Sal, cow/calves traveled at an average speed of 5.0 km/hr, which was similar to the mean speed of 5.1 km/hr observed for Phase A non-cow/calf whales. Average swimming speeds of cow/calf pairs in 1987 and 1988 were within 0.1 km/hr of each other. The swimming speeds of Phase B cow/calf pairs off Point Sal were also similar to those reported at Soberanes Point near Monterey (5.2 km/hr), but markedly faster than that reported by Mate and Harvey (1984) for four radio-tagged females with calves, which averaged 1.4 km/hr between Baja California and southern California. One of these tagged females averaged 2.2 km/hr between San Ignacio Lagoon and southern California with a maximum speed of 4.0 km/hr.

Dive Duration. The average duration of short and long dives for Phase B cows with calves was 0.5 min and 3.2 min, respectively (Table 49). Phase B cows with calves exhibited longer short dives, and shorter long dives than Phase A animals traveling in groups. This difference in diving behavior of the cow may be an adjustment to compensate for the calves' lesser diving capabilities or reflect a general tendency to "snorkel" (Poole 1984), which appears to be a defensive behavior to avoid detection by killer whales.

There is relatively little information on the dive duration of migrating cow/calf pairs. Mate and Harvey (1984) radio-tagged seven cow/calf pairs in San Ignacio Lagoon. Their mean dive was 1.6 min long, but long dives (over 1.0 min) averaged 2.6 min.

The average blow rate of cow/calf pairs during the present study was 29.6 blows/hr. Malme *et al*. (1983), measuring the blow rates of cows with calves at Soberanes Point, California, determined that cows blew an average of 24.8 times/hr. The means of individual cows ranged from 19.1 to 29.5 times/hr. The average surfacing rate for cows with calves in San Ignacio Lagoon was 40.8/hr, yielding an adjusted mean respiration rate (95% of the surfacings) of 38.8 blows/hr (Mate and Harvey 1984). Cows with calves in Magdalena Bay blew at higher rates, between 58.2 and 88.2 blows/hr (Norris *et al*. 1977). Thus, it would appear that the respiration rates of cow/calves at Point Sal were similar to those reported by Malme *et al*. (1983a) during the 1983 northbound migration past Soberanes Point. The results from Mate and Harvey (1984) were lower than those reported for radio-tagged cows with calves in Baja California breeding lagoons.

Behavior. Social behaviors generally occurred during periods of milling. During Phase B, 30% of the pods observed engaged in some milling. This proportion is greater than that observed during Phase A (18%) or the southbound migration (3%). Cow/calf pairs milled near the headland at "Reef" and in shallow water between Reef and Point Sal. At Reef, cow/calf pairs congregated before joining together and moving across the embayment toward Point Sal. Most breaching was also observed at Reef, primarily within larger pods.

More surface-active behavior was observed at Reef and Point Sal State Beach Park and included rolling, headlifts, and pectoral displays. The behavior of cow/calf pairs in this milling area was similar to that reported by Malme *et al*. (1983c) for cow/calf pairs in "Bubble Cove" near Garrapata Beach.

Between Reef and Point Sal, calves were seen two to three times more often on the shoreward side of the cow than on the seaward side. As suggested by Poole (pers. comm.) this may be a defensive posture that the cow uses to protect the calf from killer whales.

INTERACTIONS WITH OTHER CETACEANS

Associations and interactions between gray whales and other cetaceans have been documented in several other studies and include the following: 1) predator-prey relationships between killer whales and gray whales (Gilmore 1961, Morejohn 1968, Baldridge 1972, Poole 1984, Jones and Swartz 1987b); 2) feeding activity with other species (Leatherwood 1974b, Malme *et al*. 1984); 3) bow-riding of gray whales pressure waves by smaller toothed cetaceans (Leatherwood 1974b); and 4) general mixing of traveling species (Jones and Swartz 1987a, Leatherwood *et al*. 1987).

During the present study, bottlenose dolphin were seen traveling with gray whales in the surf zone between Point Sal and the Santa Maria River; this association included juvenile gray whales, cow/calf pods, and schools of 6 to 20 dolphin. There were no indications of bow-riding. Dolphins and whales were observed inside the surf zone, where the dolphin were seen surf riding. Bottlenose dolphin were also seen to circle and jump out of the water in the presence of a cow/calf pair near the Santa Maria River, when both were near a group of surfers.

No direct confrontations between gray whales and killer whales were observed at Point Sal. However, on one occasion, a pod of killer whales was seen approximately 2 km offshore. Shortly thereafter, observers sighted a cow/calf pair in the surf zone where their exhalations were difficult to see. Such behavior by gray whales could have been deliberate to avoid detection by the killer whales (Poole, pers. comm.).

RECOMMENDATIONS FOR FUTURE STUDIES

1. Monitoring of gray whales after platform installation should, if possible, be accomplished from the platform. During the present study it was found that under average conditions, the effective range for observations was about one-tenth of the maximum visual range, based on the elevation of the observer above sea level. The shorebased observation sites utilized during the present studies will probably not provide visual coverage of the area adjacent to the platform adequate to evaluate effects associated with the operation of the platform. Observations from the platform will allow closer examination of whales and their response to the platform and associated activities. It would also allow access in most weather conditions and provide more comfortable working conditions and access to shelter.

2. Aerial surveys by fixed-wing aircraft should continue to be conducted concurrently with shorebased (or platform-based) observations. While such observations only provide data on numbers of individuals, location and direction of travel at the time of fly over, they allow rapid examination a large area and an evaluation of how observations at the study site relate to the greater area.

3. The number of observation days should be increased. Because of local weather conditions and sun reflections, only the hours between 0700 and 1400 hrs are potentially useable. Observations should be restricted to between 0700 and 1200 hrs and the number of observation days increased to provide 10 to 15 days during the "peak" of the southbound and both of the northbound migration phases.

4. Pre-establish the width of the shorebased observation corridor. During the present study the size was set at "as far as you can see" and this sometimes resulted in making "marginal" observations at the visual extreme, observations that were later deleted from the database because of irregularities. It is recommended that the observation zone be restricted to a reasonable distance from the viewer.

   Based on the present study, it would appear that the effective observation range is about one-tenth of the calculated maximum at which an object at sea can be seen based on the height of the observer. For example, with the observer at 100 feet above sea level, an object on the water would be visible at a maximum distance of 21 km; however, the maximum effective observation distance would be 2.1 km.

5. Emphasize the collection of information on single individuals and cow/calf pairs, rather than individuals within pods. The primary goal is to obtain quantitative data for subsequent statistical testing after the installation of an offshore platform. It is not imperative that each whale passing be tracked, but it is imperative that each whale tracked be tracked accurately. During the present study, difficulties were encountered in the collection and subsequent treatment of data collected on individual multiple-whale pods. Under the best of conditions, specific individuals within a group cannot be identified with certainty at each surfacing for determing breathing rates, speed, dive time, etc. The tracking of pods should probably be limited to distance from shore, heading, and possibly speed if the group collectively acts "together".

6. Post-installation monitoring of gray whales should be conducted for at least three years, as there appear to be marked differences in the migratory patterns and parameters between years. At present, three migratory round trips have been sampled (as a baseline) and it is recommended that a similar period be sampled after installation.

7. If the installation of the platform and pipelines to shore are accomplished during the gray whale migration season, experienced shorebased observers should be aboard to monitor gray whale activities.

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APPENDIX A

Monterey AeroServices Aircraft Specifications

Monterey AeroServices Aircraft Specifications

The aircraft utilized was a Stinson L-5, high-winged military observation model. It is configured with a narrow cockpit (28 in.), tandem seating positions, four (4) large opening windows (30 x 18 in.), and an outward-canted greenhouse canopy which affords forward and downward visibility. When seated in the usual flying position, lateral visibility extends from five (5) degrees above the horizon to an angle of declination of 70+ degrees, which translates into a 172 ft obscured swath below the aircraft at 1,000 ft ASL. However, by shifting one's head slightly (approximately 8 in.) towards a side window, this obscured swath is reduced to 35 ft, virtually eliminating the possibility of missing a target the size of a California gray whale. Additionally, if the side windows are open during flight, observations are easily made completely beneath the aircraft at declination angles up to 106 degrees.

APPENDIX B

Theodolite Specifications and Error Analysis

Appendix B. Theodolite Specifications and Error Analysis

Calculated error measurements associated with ± 15 seconds (0.25 min) using the elevation of 117.2 m. Wild T-16 theodolite, Point Sal.

117.2 <---------elevation variable

Statute Miles	Meters	Radians	Vertical Angle Decimal Degrees	Deg	Min	+ 15 Seconds	- 15 Seconds	Total Error Meters
1	1609.0	0.072711859	4.1661	4	10.0	1607.39	1610.62	3.23
2	3218.0	0.0364040467	2.0858	2	5.1	3211.58	3224.45	12.87
3	4827.0	0.0242753216	1.3909	1	23.5	4812.58	4841.51	28.93
4	6436.0	0.0182080559	1.0432	1	2.6	6410.39	6461.81	51.42
5	8045.0	0.0145670242	0.8346	0	50.1	8005.03	8085.37	80.34
6	9654.0	0.0121394492	0.6955	0	41.7	9596.51	9712.19	115.68
7	11263.0	0.0104053779	0.5962	0	35.8	11184.82	11342.28	157.45
8	12872.0	0.0091047826	0.5217	0	31.3	12770.00	12975.65	205.65
9	14481.0	0.008093187	0.4637	0	27.8	14352.03	14612.31	260.27
10	16090.0	0.0072838985	0.4173	0	25.0	15930.94	16252.27	321.33

Calculated error measurements associated with ± 2 seconds using the elevation of 116.2 m. Zeiss ETH3 theodolite, Point Sal.

117.2 <---------elevation variable

Statute Miles	Meters	Radians	Vertical Angle Decimal Degrees	Deg	Min	+ 2 Seconds	- 2 Seconds	Total Error Meters
1	1609.0	0.072711859	4.1661	4	10.0	1608.78	1609.22	0.43
2	3218.0	0.0364040467	2.0858	2	5.1	3217.14	3218.86	1.72
3	4827.0	0.0242753216	1.3909	1	23.5	4825.07	4828.93	3.86
4	6436.0	0.0182080559	1.0432	1	2.6	6432.57	6439.43	6.86
5	8045.0	0.0145670242	0.8346	0	50.1	8039.65	8050.36	10.71
6	9654.0	0.0121394492	0.6955	0	41.7	9646.29	9661.72	15.42
7	11263.0	0.0104053779	0.5962	0	35.8	11252.51	11273.51	20.99
8	12872.0	0.0091047826	0.5217	0	31.3	12858.31	12885.72	27.42
9	14481.0	0.008093187	0.4637	0	27.8	14463.67	14498.37	34.70
10	16090.0	0.0072838985	0.4173	0	25.0	16068.61	16111.45	42.84

Approximate field of view for 30X theodolite

111 m field of view at 4,000 m
83 m field of view at 3,000 m
55.5 m field of view at 2,000 m
28 m field of view at 1,000 m

Appendix B (Cont).

Calculated error measurements associated with ± 5 seconds using the elevation of 117.2 meters. Northbound Leitz Set4 theodolite, Phase A 1987, Point Sal.

117.2 <---------elevation variable

Statute Miles	Meters	Radians	Vertical Angle Decimal Degrees	Deg	Min	+ 5 Seconds	- 5 Seconds	Total Error Meters
1	1609.0	0.072711859	4.1661	4	10.0	1608.46	1609.54	1.08
2	3218.0	0.0364040467	2.0858	2	5.1	3215.86	3220.15	4.29
3	4827.0	0.0242753216	1.3909	1	23.5	4822.18	4831.83	9.65
4	6436.0	0.0182080559	1.0432	1	2.6	6427.44	6444.58	17.14
5	8045.0	0.0145670242	0.8346	0	50.1	8031.63	8058.42	26.79
6	9654.0	0.0121394492	0.6955	0	41.7	9634.75	9673.32	38.57
7	11263.0	0.0104053778	0.5962	0	35.8	11236.81	11289.31	52.49
8	12872.0	0.0091047826	0.5217	0	31.3	12837.81	12906.37	68.56
9	14481.0	0.008093187	0.4637	0	27.8	14437.74	14524.52	86.77
10	16090.0	0.0072838985	0.4173	0	25.0	16036.62	16143.74	107.13

Calculated error measurements associated with ± 2 seconds using the elevation of 67.1 m. Zeiss ETH3 theodolite, Russel Point.

67.1 <---------elevation variable

Statute Miles	Meters	Radians	Vertical Angle Decimal Degrees	Deg	Min	+ 2 Seconds	- 2 Seconds	Total Error Meters
1	1609.0	0.0416787706	2.3880	2	23.3	1608.63	1609.37	0.75
2	3218.0	0.0208484394	1.1945	1	11.7	3216.50	3219.50	2.99
3	4827.0	0.0139000784	0.7964	0	47.8	4823.63	4830.37	6.74
4	6436.0	0.0104253525	0.5973	0	35.8	6430.02	6441.99	11.97
5	8045.0	0.0083403908	0.4779	0	28.7	8035.66	8054.36	18.71
6	9654.0	0.0069503749	0.3982	0	23.9	9640.55	9667.49	26.94
7	11263.0	0.0059574897	0.3413	0	20.5	11244.70	11281.36	36.66
8	12872.0	0.0052128179	0.2987	0	17.9	12848.10	12895.99	47.89
9	14481.0	0.0046336247	0.2655	0	15.9	14450.76	14511.37	60.61
10	16090.0	0.0041702679	0.2389	0	14.3	16052.68	16127.50	74.82

Approximate field of view for 30X theodolite

111 m field of view at 4,000 m
83 m field of view at 3,000 m
55.3 m field of view at 2,000 m
28 m field of view at 1,000 m

Appendix B (Cont).

Calculated error measurements associated with ± 5 seconds using the elevation of 67.1 meters. Leitz SET4, Mussel Point.

67.1 <---------elevation variable

Statute Miles	Meters	Radians	Vertical Angle Decimal Degrees	Deg	Min	+ 5 Seconds	- 5 Seconds	Total Error Meters
1	1609.0	0.0416787736	2.3880	2	23.3	1608.06	1609.94	1.87
2	3218.0	0.0208484394	1.1945	1	11.7	3214.26	3221.75	7.49
3	4827.0	0.0139000786	0.7964	0	47.8	4818.59	4835.44	16.84
4	6436.0	0.0104253525	0.5973	0	35.8	6421.07	6451.00	29.94
5	8045.0	0.0083403908	0.4779	0	28.7	8021.68	8068.46	46.78
6	9654.0	0.0069503749	0.3982	0	23.9	9620.44	9687.80	67.36
7	11263.0	0.0059574897	0.3413	0	20.5	11217.34	11309.03	91.68
8	12872.0	0.0052128179	0.2987	0	17.9	12812.40	12932.15	119.75
9	14481.0	0.0046336247	0.2655	0	15.9	14405.62	14557.18	151.56
10	16090.0	0.0041702679	0.2389	0	14.3	15996.99	16184.10	187.11

Approximate field of view for 30X theodolite

111 m field of view at 4,000 m
83 m field of view at 3,000 m
55.5 m field of view at 2,000 m
28 m field of view at 1,000 m

APPENDIX C

Metric Conversion Table

CONVERSION FACTORS

To Convert	Into	Multiply By
milimeters (mm)	inches	0.03937
centimeters (cm)	inches	0.3937
meters (m)	feet	3.281
meters (m)	fathoms	0.5467
kilometers (km)	miles	0.6214
kilometers (km)	nautical miles	0.5397
square meters (m^2)	square feet	10.76
square kilometers (km^2)	square miles	0.3861
hectares (ha)	acres	2.471
liters (L)	gallons	0.2642
cubic meters (m^3)	cubic feet	35.31
cubic meters (m^3)	acre-feet	0.0008106
milligrams (mg)	ounces	0.00003527
grams (gm)	ounces	0.03527
kilograms (kg)	pounds	2.205
metric tons (mt)	pounds	2205.0
metric tons (mt)	short tons	1.102
kilocalories (kcal)	BTU	3.968
inches (in.)	milimeters	25.40
inches (in.)	centimeters	2.54
feet (ft)	meters	0.3048
fathoms (fm)	meters	1.829
miles (mi)	kilometers	1.609
nautical miles (nm)	kilometers	1.853
square feet (ft^2)	square meters	0.0929
square miles (mi^2)	square kilometers	2.590
acres	hectares	0.4047
gallons (gal)	liters	3.785
cubic feet (ft^3)	cubic meters	0.02831
acre-feet	cubic meters	1233.6
ounces (oz)	milligrams	28353.00
ounces (oz)	grams	28.35
pounds (lbs)	kilograms	0.4536
pounds (lbs)	metric tons	0.0004536
short tons (ton)	metric tons	0.9078
BTU	kilocalories	0.2520
Fahrenheit degrees (°F)	1.8 x °C + 32	
Celsius degrees (°C)	0.5556 x °F - 32	

APPENDIX D

Aerial Survey Data

Appendix D-1. Gray whale sighting information, January 1987.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Aerial sighting information, January 1987.							
21 Jan 1987	0950-1225	5	19	3.8	2.6	1.9	7.3
22 Jan 1987	0855-1140	7	22	3.1	2.7	2.6	8.1
22 Jan 1987	1300-1550	11	37	3.4	2.8	3.9	13.2
23 Jan 1987	1110-1425	8	23	2.9	3.3	2.4	7.0
Survey Total		31	101	3.3	11.4	2.7	8.9
Non-Cow/Calves		26	88	3.3	11.4	2.3	7.7
Cow/Calves (Pairs)		3	6	2.0	11.4	0.3	0.5
2 Adults/1 Calf		1	3	4.0	11.4	0.1	0.3
Double Cow/Calves		1	4	4.0	11.4	0.1	0.4

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
b) Pod composition (all data)				
1	5	16.1	5	5.0
2	5	13.3	10	9.9
3	5	16.1	15	14.9
4	3	9.7	12	11.9
5	5	16.1	25	24.8
6	1	3.2	6	5.9
7	1	3.2	7	6.9
8	1	3.2	8	7.9
Cow/Calves (Pairs)	3	9.7	6	5.9
2 Adults/1 Calf	1	3.2	3	3.0
Double Cow/Calves	1	3.2	4	4.0
Survey Total	31	100.0	101	100.0
Non-Cow/Calves	26	83.9	88	87.1
Cow/Calves (Pairs)	3	9.7	6	5.9
2 Adults/1 Calf	1	3.2	3	3.0
Double Cow/Calves	1	3.2	4	4.0

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
c) Pod composition (data for study area only)				
1	5	16.7	5	5.1
2	4	13.3	8	8.1
3	5	16.7	15	15.2
4	3	10.0	12	12.1
5	5	16.7	25	25.3
6	1	3.3	6	6.1
7	1	3.3	7	7.1
8	1	3.3	8	8.1
Cow/Calves (Pairs)	3	10.0	6	6.1
2 Adults/1 Calf	1	3.3	3	3.0
Double Cow/Calves	1	3.3	4	4.0
Survey Total	30	100.0	99	100.0
Non-Cow/Calves	25	83.3	86	86.9
Cow/Calves (Pairs)	3	10.0	6	6.1
2 Adults/1 Calf	1	3.3	3	3.0
Double Cow/Calves	1	3.3	4	4.0

Appendix D-2. Gray whale sighting information, March 1987.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Aerial sighting information, March 1987							
16 Mar 1987	1022-1232	6	13	2.2	2.2	2.7	5.9
16 Mar 1987	1352-1435	3	9	3.0	1.0	3.0	9.0
18 Mar 1987	1020-1215	7	19	2.7	1.9	3.7	10.0
19 Mar 1987	0900-1125	8	19	2.4	2.6	3.1	7.3
27 Mar 1987	1220-1452	10	29	2.9	2.5	4.0	11.6
28 Mar 1987	1025-1251	9	23	2.6	2.6	3.5	8.8
29 Mar 1987	1123-1212	3	8	2.7	0.8	3.8	10.0
Survey Total		46	120	2.6	13.6	3.4	8.8
Non-Cow/Calves		44	113	2.6	13.6	3.2	8.3
2 Adults/1 Calf		1	3	2.0	13.6	0.1	0.2
Double Cow/Calves		1	4	4.0	13.6	0.1	0.3

Pod Size	No. of Pods	% of Total	No. of Indv.	% of Total
b) Pod composition (all data)				
1	10	21.7	10	8.3
2	14	30.4	28	23.3
3	11	23.9	33	27.5
4	5	10.9	20	16.7
5	3	6.5	15	12.5
7	1	2.2	7	5.8
2 Adults/1 Calf	1	2.2	3	2.5
Double Cow/Calves	1	2.2	4	3.3
Survey Total	46	100.0	120	100.0
Non-Cow/Calves	44	94.7	113	94.2
2 Adults/1 Calf	1	2.2	3	2.5
Double Cow/Calves	1	2.2	4	3.3

Pod Size	No. of Pods	% of Total	No. of Indv.	% of Total
c) Pod composition (data for study area only)				
1	9	24.3	9	9.2
2	9	24.3	18	18.4
3	9	24.3	27	27.6
4	5	13.5	20	20.0
5	2	5.4	10	10.2
7	1	2.7	7	7.1
2 Adults/1 Calf	1	2.7	3	3.1
Double Cow/Calves	1	2.7	4	4.1
Survey Total	37	100.0	98	100.0
Non-Cow/Calves	35	94.6	91	92.9
2 Adults/1 Calf	1	2.7	3	3.1
Double Cow/Calves	1	2.7	4	4.0

Appendix D-3. Gray whale sighting information, May 1987.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Aerial sighting information, May 1987							
21 May 1987	0755-1040	4	7	1.8	2.7	1.5	2.6
	1250-1525	6	9	1.5	2.6	2.3	3.5
Survey Total		10	16	1.6	5.3	1.9	3.0
Non-Cow/Calves		5	6	1.2	5.3	0.9	1.1
Cow/Calf Pairs		5	10	2.0	5.3	0.9	1.9

Pod Size	No. of Pods	% of Total	No. of Indv.	% of Total
b) Pod composition (all data)				
1	4	40.0	4	25.0
2	1	10.0	2	12.5
All Cow/Calves	5	50.0	10	62.5
Survey Total	10	100.0	16	100.0
Non-Cow/Calves	5	50.0	6	37.5
Cow/Calves	5	50.0	10	62.5

Pod Size	No. of Pods	% of Total	No. of Indv.	% of Total
c) Pod composition (data for study area only)				
1	3	33.3	3	20.0
2	1	11.1	2	13.3
All Cow/Calves	5	55.6	10	66.7
Survey Total	9	100.0	15	100.0
Non-Cow/Calves	4	44.4	5	33.3
Cow/Calves	5	55.6	10	66.7

Appendix D-4. Gray whale sighting information, March 1988.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Aerial sighting information, March 1988							
8 Mar 1988	0953-1215	13	58	4.5	2.4	5.4	24.2
8 Mar 1988	1356-1605	8	18	2.3	2.2	3.6	8.2
12 Mar 1988	1545-1827	11	37	3.4	2.7	4.1	13.7
13 Mar 1988	0955-1205	7	17	2.4	2.2	3.2	7.7
13 Mar 1988	1605-1830	5	14	2.8	2.4	2.1	5.8
14 Mar 1988	0950-1245	6	13	2.2	2.7	2.2	4.8
15 Mar 1988	1408-1630	14	36	2.6	2.4	5.8	15.0
16 Mar 1988	0945-1155	6	12	2.0	2.1	2.9	5.7
16 Mar 1988	1305-1540	10	22	2.2	2.5	4.0	8.8
Survey Total		80	227	2.8	21.6	3.7	10.5
Non-Cow/Calves		77	221	2.9	21.6	3.6	10.2
Cow/Calves		3	6	2.0	21.6	0.1	0.3

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
b) Pod Composition, all data				
1	20	25.0	20	8.8
1	22	27.5	44	19.4
3	17	21.3	51	22.5
4	9	11.3	36	15.9
5	6	7.5	30	13.2
6	1	1.3	6	2.6
14	1	1.3	14	6.2
18	1	1.3	18	7.9
Cow/Calves	2	2.5	4	1.8
Mixed Pod	1	1.3	4	1.8
Survey Total	80	100.0	227	100.0
Non-Cow/Calves	77	96.3	219	96.5
Cow/Calves	2	2.5	4	1.8
Mixed Pods	1	1.3	4	1.8

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
c) Pod composition, study area				
1	14	24.1	14	8.5
2	17	29.3	34	20.7
3	12	20.7	36	22.0
4	5	8.6	20	12.2
5	6	10.3	30	18.3
6	1	1.7	6	3.7
18	1	1.7	18	11.1
Cow/Calves	1	1.7	2	1.2
Mixed Pods	1	1.7	4	2.4
Survey Total	58	100.0	164	100.0
Non-Cow/Calves	56	96.6	158	96.3
Cow/Calves	1	1.7	2	1.2
Mixed Pods	1	1.7	4	2.4

Appendix D-5. Summary of all aerial observations, May 1986-March 1988.

Date	Pod #	N	Distance Offshore (km)	Heading (true)	(magnetic)	Location Lat.		Long.	Block	Depth
4MAY86	1	1	6.50	351	335	34 57	x	120 43.5	2	2
	2	2MY	11.10	6	350	34 52	x	120 44.5	2	2
	3	1	6.00	40	40	34 48	x	120 41	1	2
21JAN87 morning	1	3	17.80	191	175	35 02	x	120 37	4	3
	2	7	17.00	176	160	35 00	x	120 44	4	4
	*3	2	0.50	201	185	34 59	x	120 39		
	4	2	20.50	166	150	35 03	x	120 51	5	4
	5	5	17.50	193	177	34 57	x	120 51	5	4
22JAN87 morning	6	5	22.00	201	185	35 03	x	120 52	5	4
	7	2	14.00	176	160	35 02	x	120 47	3	3
	8	1	16.80	186	170	35 01	x	120 49	4	4
	9	4	19.00	161	145	35 00	x	120 51	5	4
	10	2MY	31.00	181	165	34 59	x	120 59	7	6
	11	3	13.00	156	140	34 56	x	120 48	3	4
	12	5	4.50	186	170	34 54	x	120 43	1	2
22JAN87 afternoon	13	3	24.50	176	160	35 06	x	120 53	6	4
	14	2	16.00	171	155	35 03	x	120 48	3	3
	15	6	22.50	196	180	35 01	x	120 53	6	4
	16	5	11.80	191	175	35 00	x	120 46	2	3
	17	1	17.00	216	200	34 59	x	120 50	4	4
	18	2MY	12.30	181	165	34 58	x	120 47	3	3
	19	8	23.50	181	165	34 57	x	120 55	6	5
	20	2	8.00	166	150	34 56	x	120 45	2	3
	21	3MY	14.30	156	140	34 56	x	120 49	4	4
	22	4	31.50	176	160	34 54	x	120 01	7	7
	23	1	9.00	171	155	34 53	x	120 46	2	3
23JAN87 morning	24	1	27.80	186	170	35 04	x	120 55	6	5
	25	1	18.00	156	140	35 01	x	120 50	4	4
	26	5	15.30	186	170	34 58	x	120 53	4	4
	27	4	20.80	196	180	34 57	x	120 43	6	4
	28	2MY	5.50	176	160	34 57	x	120 43	1	2
	29	6MY	22.80	161	145	34 54	x	120 55	6	5
	30	3	15.00	171	155	34 53	x	120 50	4	4
	31	3	12.50	191	175	34 52	x	120 48	3	4
16MAR87 morning	*1	3	1.00	346	330	35 02	x	120 37		
	2	2	9.00	21	5	35 00	x	120 44	2	2
	3	1	16.50	326	310	34 59	x	120 49	5	4
	4	2	19.25	1	345	34 59	x	120 51	6	4
	5	3	18.25	6	350	34 57	x	120 51	6	4
	6	2	22.50	6	350	34 46	x	120 52	6	4
16MAR87 afternoon incomplete	*7	3	6.00	351	335	35 01	x	120 42		
	8	4	8.00	356	340	34 46	x	120 43	2	3
	*9	2	9.00	11	355	34 42	x	120 42		
18MAR87 morning	10	4	16.50	256	240	34 56	x	120 50	5	4
	11	3	18.00	316	300	34 52	x	120 51	6	4
	12	2	18.00	326	310	34 50	x	120 49	5	4
	13	6MY	11.25	1	345	34 46	x	120 45	3	3
	*14	2	11.00	11	355	34 44	x	120 44		
	15	1	14.50	26	10	34 59	x	120 48	4	4
	16	3	17.75	16	360	34 59	x	120 50	5	4
19MAR87 morning	*17	1	1.75	1	345	35 01	x	120 39		
	18	3	6.00	316	300	34 58	x	120 43	2	2
	19	5	9.50	321	305	34 47	x	120 44	2	3
	20	1	11.75	346	330	34 46	x	120 45	3	3
	21	2	10.00	6	350	34 52	x	120 46	3	3
	22	1	10.50	341	325	34 54	x	120 47	4	4
	23	4	17.75	346	330	34 59	x	120 50	5	4
	24	2	18.00	1	345	34 48	x	120 49	5	4
27MAR87 afternoon	*25	2	0.50	346	330	35 04	x	120 37		
	26	3	9.00	286	270	34 57	x	120 45		
	27	3	18.25	301	285	34 57	x	120 51	3	3
	28	1	15.75	331	315	34 53	x	120 50	6	4
	29	2	14.50	296	280	34 52	x	120 49	5	4
	30	4	16.50	11	355	35 00	x	120 49	5	4
	31	1	18.00	56	40	34 51	x	120 51	5	4
	32	5	20.50	16	360	34 59	x	120 52	6	4
	33	3	31.75	6	350	34 59	x	120 59	8	4
	34	5	14.25	6	350	35 02	x	120 47	8	6

Appendix D-5 (Cont).

Date	Pod #	N	Distance Offshore (km)	Heading (true)	(magnetic)	Location Lat.		Long.	Block	Depth
28MAR87 morning	*35	2	0.50	346	330	35 00	x	120 38		
	*36	3MY	9.50	346	330	34 59	x	120 45		
	37	1	9.25	1	345	34 53	x	120 46		
	38	1	15.75	6	350	34 53	x	120 50		
	39	3	15.50	31	15	34 54	x	120 50	3	3
	40	1	18.50	316	300	34 54	x	120 52	3	3
	41	7	24.00	11	355	34 47	x	120 53	5	4
	42	3	28.50	6	350	35 00	x	120 57	5	4
	*43	2	19.00	311	295	35 05	x	120 50	6	4
29MAR87 morning	44	4	9.30	6	350	34 58	x	120 43	7	5
	45	2	3.25	11	355	34 55	x	120 42		
	46	2	13.00	356	340	34 46	x	120 46	8	6
21MAY87 morning	1	2MY	2.80	6	350	34 53	x	120 41	1	1
	2	1	10.00	16	360	34 48	x	120 44	2	3
	3	2	12.00	1	345	34 55	x	120 48	4	4
	4	2MY	6.30	40	40	34 59	x	120 43	2	2
21MAY87 afternoon	*5	1	1.00	336	320	34 59	x	120 39		
	6	2MY	2.00	11	355	34 56	x	120 41	1	1
	7	2MY	6.00	351	335	34 47	x	120 42	1	2
	8	1	11.00	16	360	35 00	x	120 46	3	3
	9	1	12.80	356	340	34 52	x	120 48	4	4
	10	2MY	8.30	346	330	34 58	x	120 45	3	3
8MAR88 morning	1	1	4.8	1	345	34 49	x	120 40	1	2
	2	2	10.8	356	340	34 49	x	120 44	2	3
	3	1	9	346	330	34 53	x	120 46	3	3
	4	1	8.5	316	300	34 54	x	120 46	3	3
	5	2MY	11	331	315	34 46	x	120 45	3	3
	6	3	5.5	316	300	34 54	x	120 44	2	2
	7	3	23.5	356	340	34 47	x	120 53	7	5
	8	2	16	16	360	34 58	x	120 50	5	4
	9	4	18.5	26	10	35 00	x	120 51	6	4
	*10	14	18	31	15	35 02	x	120 51		
	11	3	17	16	360	34 47	x	120 49	5	4
	12	18	15	16	360	34 46	x	120 48	4	4
	13	4	18.5	26	10	35 00	x	120 51	6	4
8MAR88 afternoon	*14	3	11	356	340	35 03	x	120 45		
	15	1	12.5	1	345	35 00	x	120 47	4	3
	16	5	13.5	351	335	34 59	x	120 48	4	4
	17	1	16.5	16	360	34 48	x	120 48	4	4
	18	3	19.5	26	10	34 58	x	120 52	6	4
	19	2	18	16	360	34 55	x	120 52	6	4
	*20	2	17	11	355	35 01	x	120 50		
	*21	1	12	1	345	35 01	x	120 46		
17MAR88 afternoon	22	3	27	31	15	34 52	x	120 58	8	6
	23	6	33	21	5	34 44	x	121 00	8	7
	24	4	16.5	1	345	34 52	x	120 51	6	4
	25	2	16	16	360	34 58	x	120 50	5	4
	26	4MY	15	11	355	34 59	x	120 49	5	4
	27	2	12	6	350	34 56	x	120 48	4	4
	28	5	14	6	350	34 47	x	120 47	4	4
	29	3	10.5	16	360	34 51	x	120 46	3	3
	30	2	9	36	20	34 46	x	120 44	2	3
	31	2	5.5	11	355	34 52	x	120 43	2	2
	*32	4	10	1	345	35 01	x	120 45		
13MAR88 morning	*33	1	14	6	350	35 04	x	120 47		
	34	2	16.5	346	330	34 53	x	120 51	6	4
	*35	2	12	26	10	35 02	x	120 46		
	*36	2MY	7	16	360	35 02	x	120 43		
	37	3	9.5	11	355	34 47	x	120 44	2	3
	38	2	11	36	20	34 45	x	120 45	3	3
	39	5	12	16	360	34 51	x	120 47	4	4
13MAR88 afternoon	40	1	11	6	350	34 57	x	120 47	4	3
	41	3	12.5	11	355	34 47	x	120 46	3	3
	42	4	8	356	340	34 52	x	120 45	3	3
	*43	4	13	326	310	35 01	x	120 47		
	44	2	19.5	16	360	34 58	x	120 52	6	4

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Appendix D-5 (Cont).

Date	Pod #	N	Distance Offshore (km)	Heading (true)	(magnetic)	Location Lat.		Long.	Block	Depth
14MAR88 morning	*45	4	19.5	301	285	35 02	x	120 50		
	*46	2	0.8	11	355	34 53	x	120 39		
	47	1	2.5	6	350	34 46	x	120 40	1	2
	*48	3	9	31	15	34 44	x	120 43		
	49	1	7	16	360	34 54	x	120 45	3	3
	50	2	7.5	6	350	34 59	x	120 44	2	2
15MAR88 afternoon	*51	1	2.5	1	345	34 48	x	120 39		
	*52	3	0.5			34 57	x	120 39		
	*53	3	11.8	6	350	34 02	x	120 46		
	54	5	10	16	360	34 58	x	120 46	3	3
	55	3	10.5	11	355	34 55	x	120 47	4	4
	56	2	12.3	21	5	34 49	x	120 45	3	3
	*57	1	13.8	16	360	34 44	x	120 46		
	58	3	9.5	16	360	34 47	x	120 44	2	3
	59	2	4	6	350	34 53	x	120 43	2	2
	60	5	7.5	1	345	34 59	x	120 44	2	2
	*61	4	4.5	21	5	35 02	x	120 41		
	*62	2	1.5	31	15	34 49	x	120 38		
	*63	1	0.5	16	360	34 50	x	120 37		
	*64	1	0.5	316	300	34 54	x	120 39		
16MAR88 morning	65	1	5.5	16	360	34 54	x	120 44	2	2
	66	1	4	16	360	34 53	x	120 43	2	2
	67	4	9			34 46	x	120 44	2	3
	68	1	16	21	5	34 48	x	120 48	4	4
	*69	2	15.5	1	345	35 03	x	120 48		
	*70	3	7.8	356	340	35 02	x	120 43		
16MAR88 afternoon	71	3	27	31	15	34 52	x	120 58	8	6
	72	1	25.8	16	360	34 46	x	120 55	7	5
	73	2	19.5	271	255	34 58	x	120 52	6	4
	74	1	21.8	16	360	34 49	x	120 51	6	4
	75	2	19.5	16	360	34 46	x	120 51	6	4
	76	5	14.5	21	5	34 51	x	120 49	5	4
	77	2	13	26	10	34 58	x	120 48	4	4
	78	1	15.5	6	350	34 50	x	120 47	4	4
	79	2	9.5	11	355	34 47	x	120 44	2	3
	80	3	4.5	16	360	34 55	x	120 43	2	2

Appendix D-6. Density of grey whales and pods by migration phase and survey.

Southbound

Block	Area (km²)	Whales	Sightings	Pods	Sightings	Whales	Sightings	Pods	Sightings
					Number per km²				
		Non-Cow/Calf Pairs				Cow/Calf Pairs			
2	385.28	5	0.013	1	0.003	2	0.005	1	0.003
3	385.28	8	0.021	3	0.008	0	0.000	0	0.000
4	385.28	10	0.026	4	0.010	2	0.005	1	0.003
5	385.28	21	0.055	7	0.018	3	0.008	1	0.003
6	385.28	16	0.042	4	0.010	0	0.000	0	0.000
7	770.56	22	0.029	5	0.006	4	0.005	1	0.001
8	770.56	4	0.005	1	0.001	2	0.003	1	0.001
	3467.52	86	0.027 ± 0.017	25	0.007 ± 0.006	13	0.004 ± 0.003	5	0.001 ± 0.001

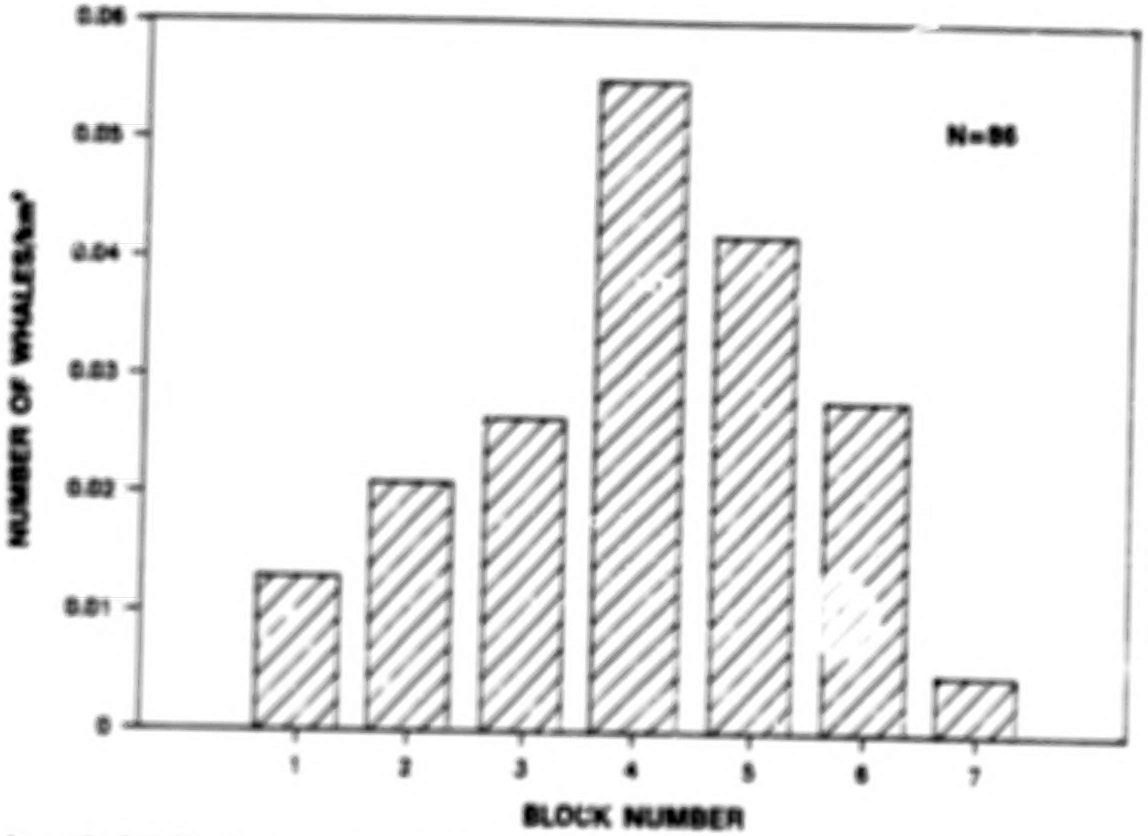
Northbound, Phase A

Block	Area (km²)	Whales	Sightings	Pods	Sightings
					Number per km²
			March 1987		
1	722.4	2	0.003	2	0.003
2	722.4	18	0.025	5	0.007
3	619.2	9	0.015	5	0.008
4	516.25	2	0.004	2	0.004
5	516.25	27	0.052	10	0.019
6	516.25	20	0.039	8	0.015
7	1032	7	0.007	1	0.001
8	1032	6	0.006	2	0.002
	5676.75	91	0.019 ± 0.016	35	0.006 ± 0.007
			May 1987		
1	206.4	0	0.000	0	0.000
2	206.4	1	0.005	1	0.005
3	206.4	1	0.005	1	0.005
4	206.4	3	0.015	2	0.010
5	206.4	0	0.000	0	0.000
6	206.4	0	0.000	0	0.000
7	412.8	0	0.000	0	0.000
8	412.8	0	0.000	0	0.000
	2064	5	0.004 ± 0.005	4	0.002 ± 0.004
			March 1988		
1	928.8	2	0.002	2	0.002
2	928.8	35	0.038	14	0.015
3	928.8	22	0.024	9	0.010
4	928.8	45	0.048	12	0.013
5	928.8	12	0.013	4	0.004
6	928.8	26	0.028	10	0.011
7	1857.6	4	0.002	2	0.001
8	1857.6	12	0.006	3	0.002
	9288	158	0.020 ± 0.017	56	0.006 ± 0.006

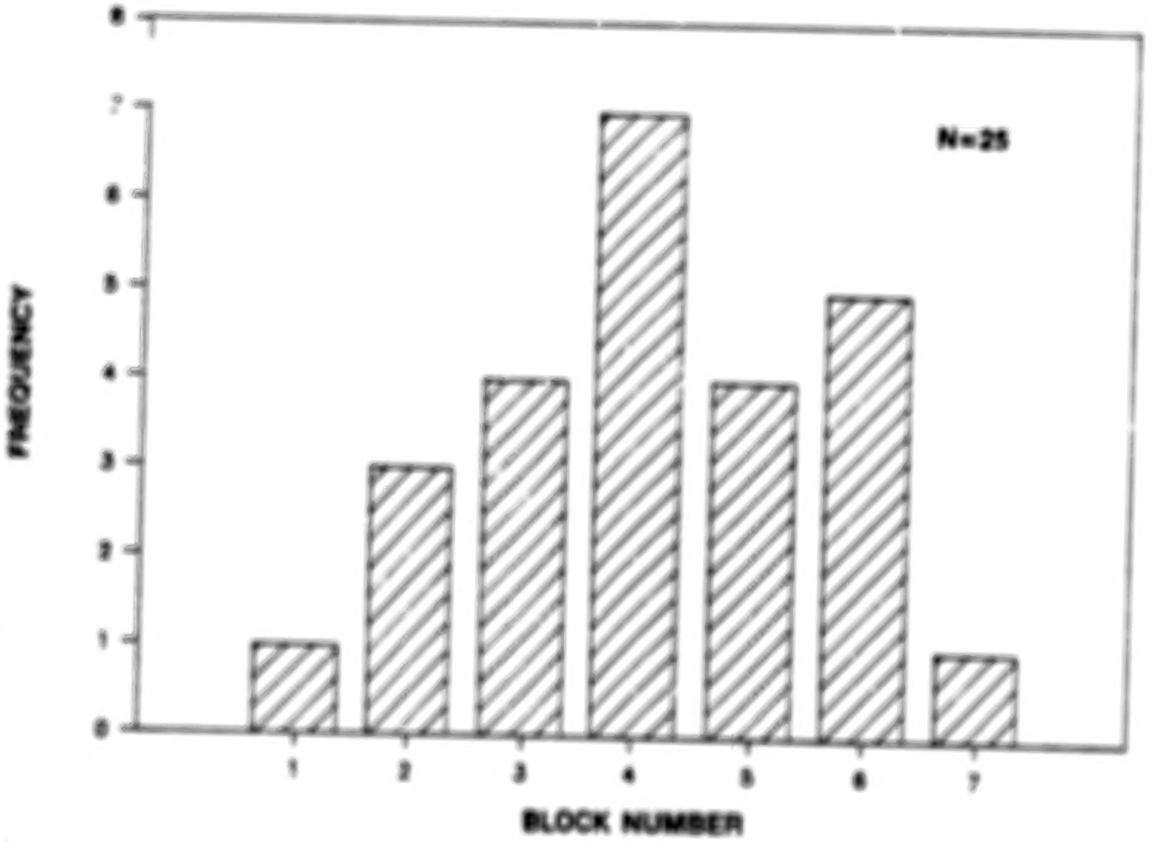
Appendix D-6 (Cont).

Northbound, Phase I

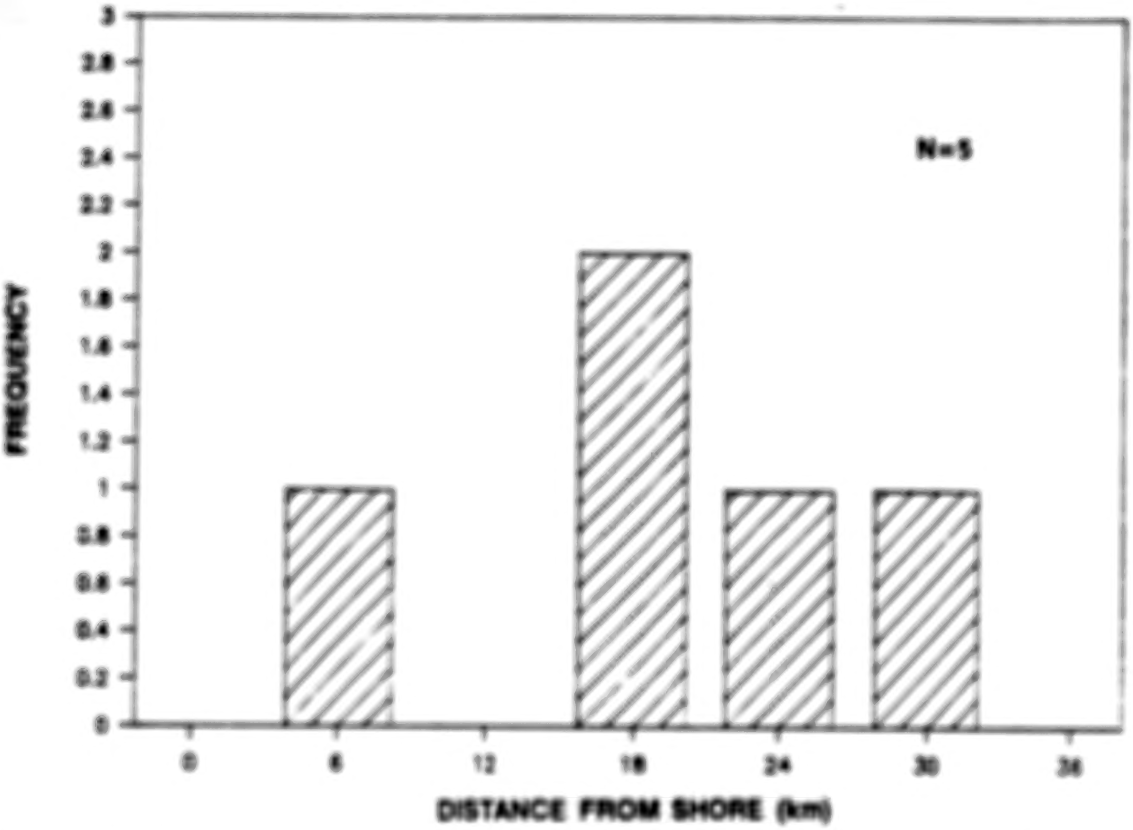
			Number per km²		
Block	Area (km²)	Whales	Sightings	Pods	Sightings
			March 1987		
1	722.4	0	0.000	0	0.000
2	722.4	0	0.000	0	0.000
3	619.2	7	0.013	2	0.003
4	516.25	0	0.000	0	0.000
5	516.25	0	0.000	0	0.000
6	516.25	0	0.000	0	0.000
7	1032	0	0.000	0	0.000
8	1032	0	0.000	0	0.000
	5676.75	7	0.001 ± 0.005	2	0.0004 ± 0.0011
			May 1987		
1	206.4	6	0.029	3	0.015
2	206.4	2	0.010	1	0.005
3	206.4	2	0.010	1	0.005
4	206.4	0	0.000	0	0.000
5	206.4	0	0.000	0	0.000
6	206.4	0	0.000	0	0.000
7	412.8	0	0.000	0	0.000
8	412.8	0	0.000	0	0.000
	2064	10	0.006 ± 0.010	5	0.002 ± 0.005
			March 1988		
1	928.8	0	0.000	0	0.000
2	928.8	0	0.000	0	0.000
3	928.8	2	0.002	1	0.001
4	928.8	0	0.000	0	0.000
5	928.8	4	0.004	1	0.001
6	928.8	0	0.000	0	0.000
7	1857.6	0	0.000	0	0.000
8	1857.6	0	0.000	0	0.000
	9288	6	0.001 ± 0.002	2	0.0002 ± 0.005



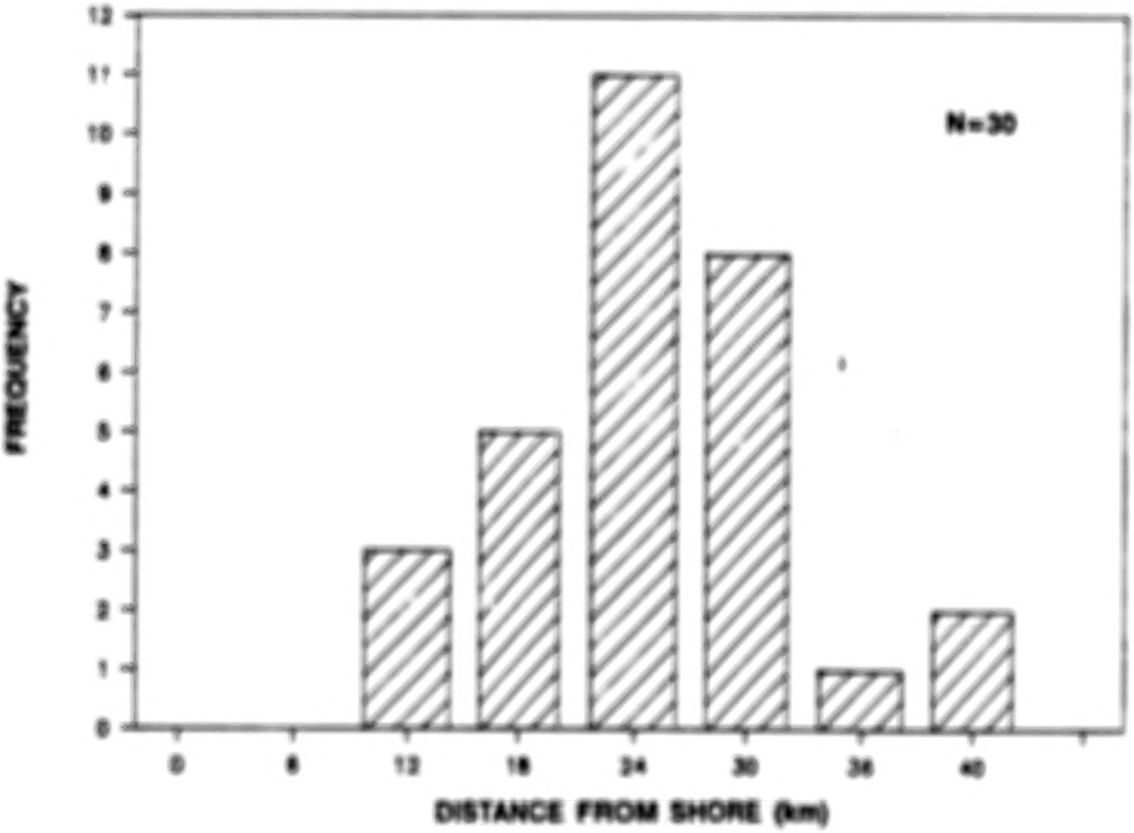
Appendix D-7. Density of gray whales by block number, southbound migration.



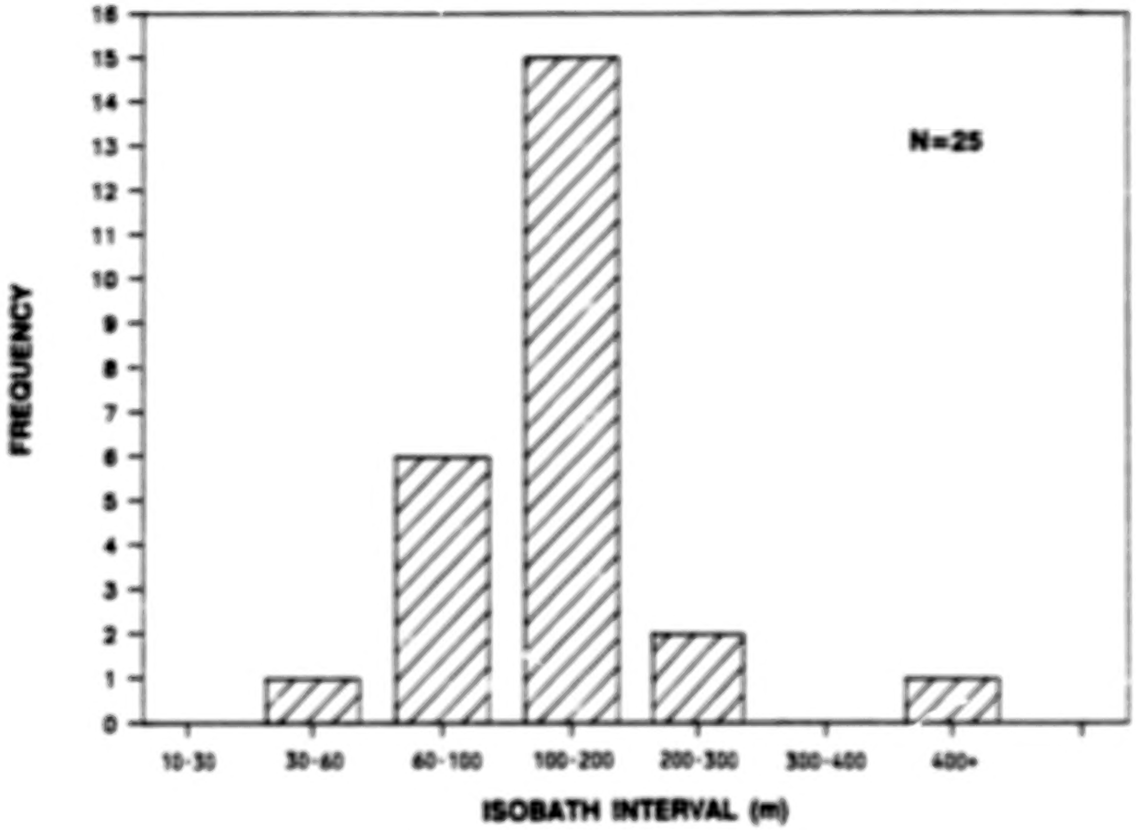
Appendix D-8. Numbers of non-cow/calf pairs by block number in the study area, southbound migration.



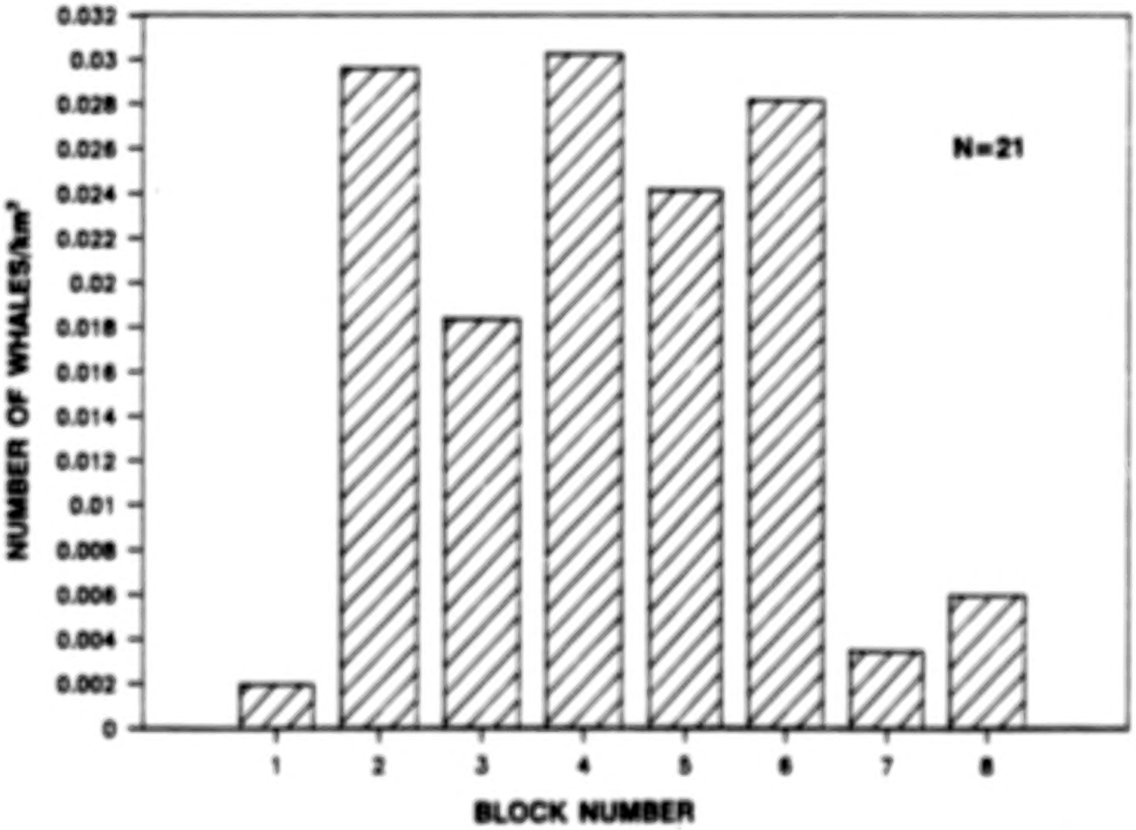
Appendix D-9. Numbers of cow/calf pairs as a function of distance from shore, southbound migration.



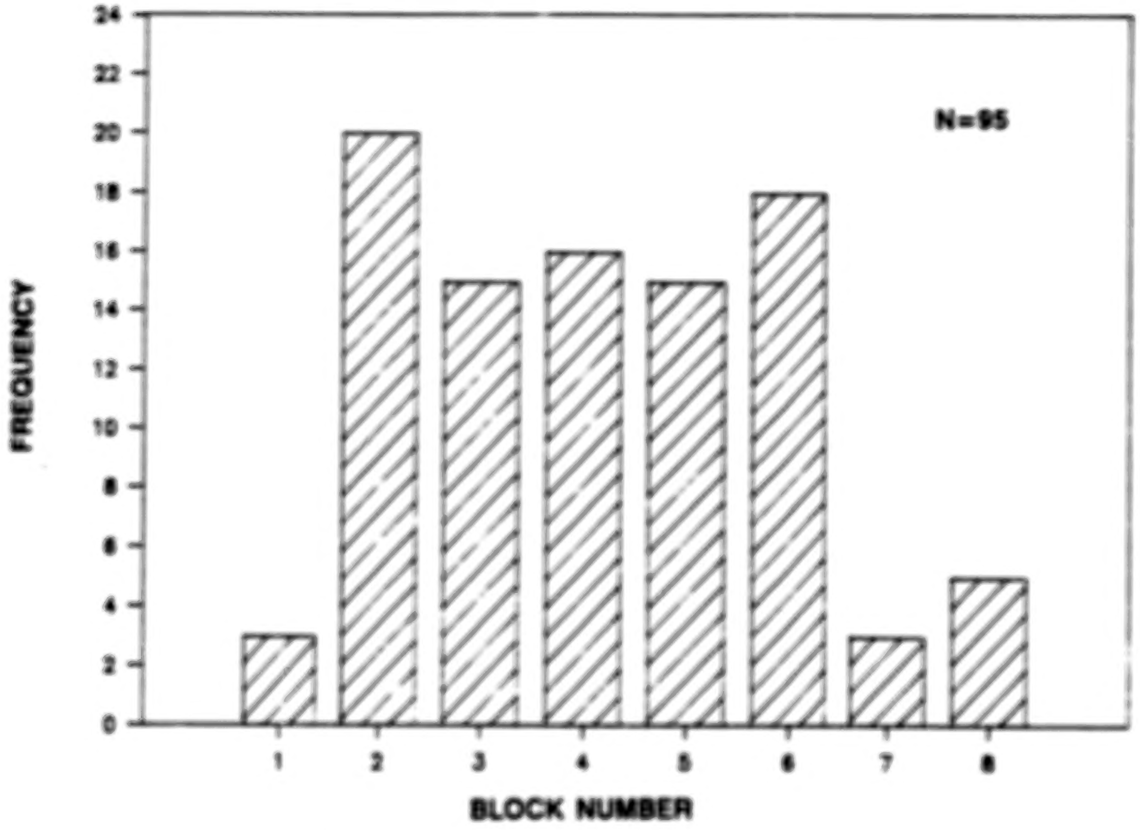
Appendix D-10. Numbers of non-cow/calf pairs as a function of distance from shore, southbound migration.



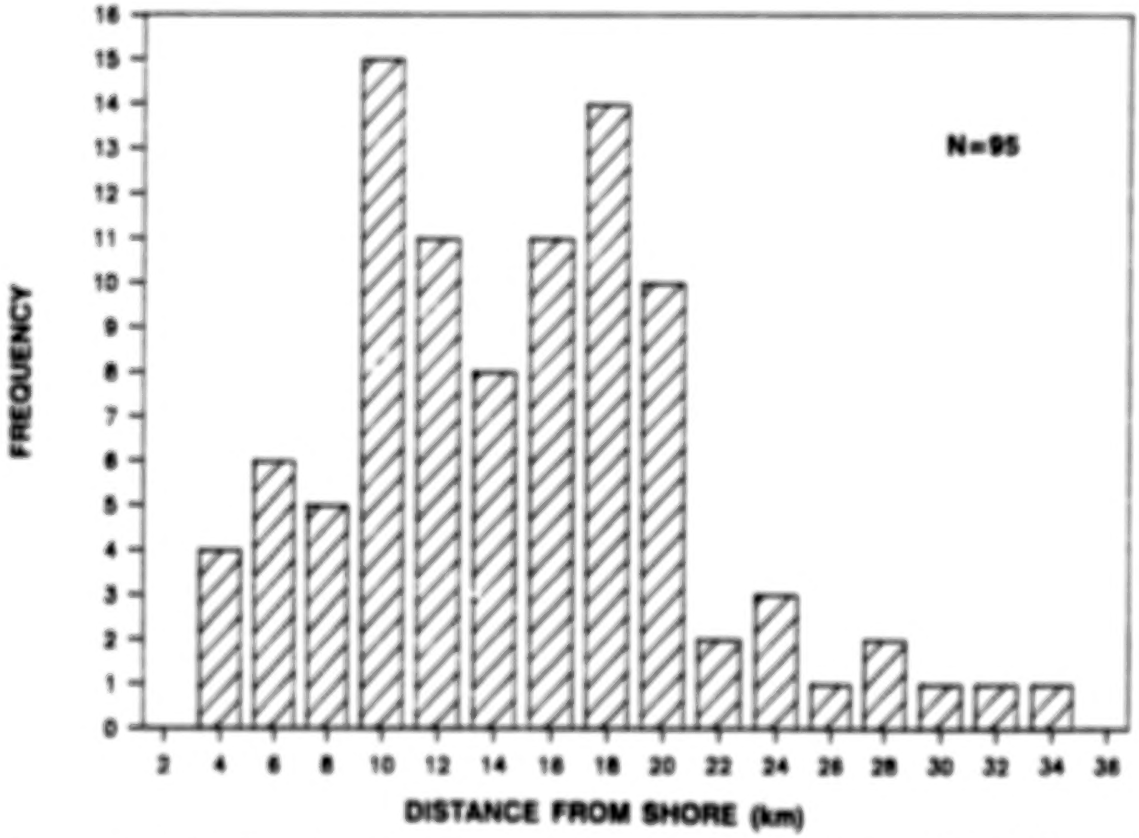
Appendix D-11. Numbers of gray whales as a function of water depth, southbound migration.



Appendix D-12. Numbers of gray whale pods as a function of block number, northbound, Phase A migration.



Appendix D-13. Numbers of gray whales as a function of block number, northbound, Phase A migration.



Appendix D-14. Numbers of gray whales as a function of distance from shore, northbound, Phase A migration.

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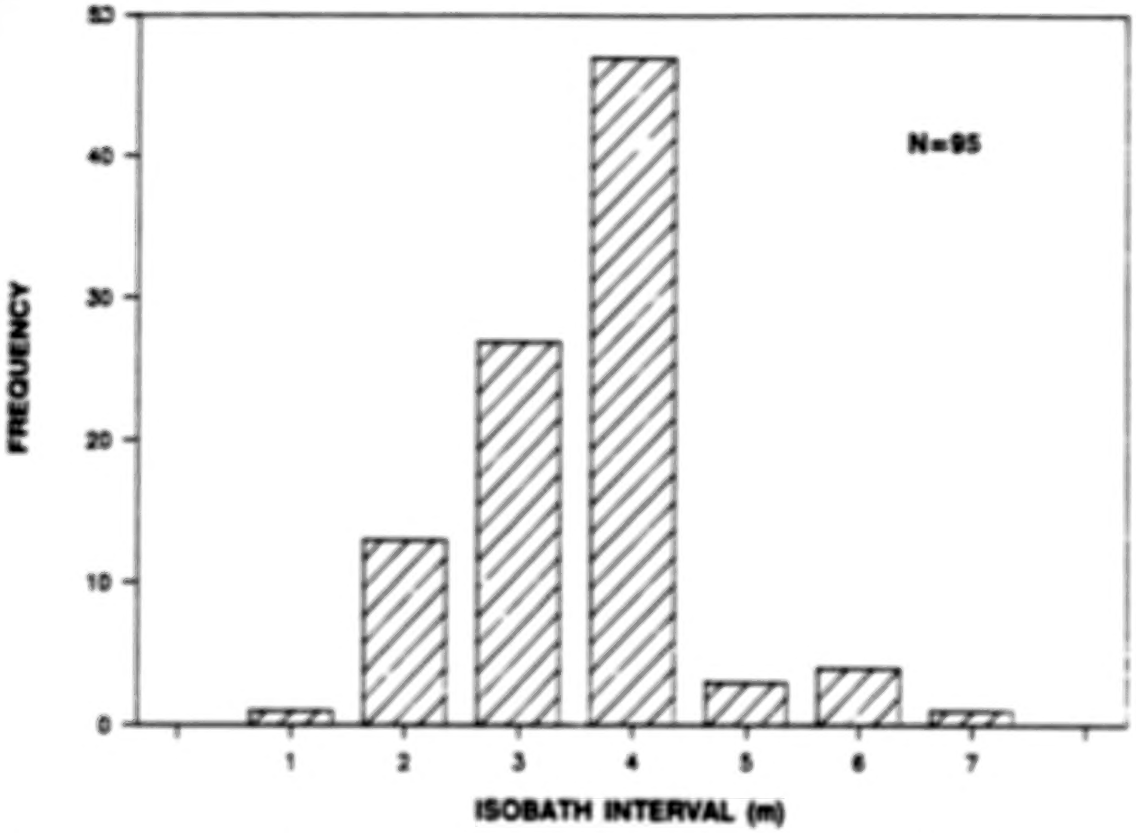
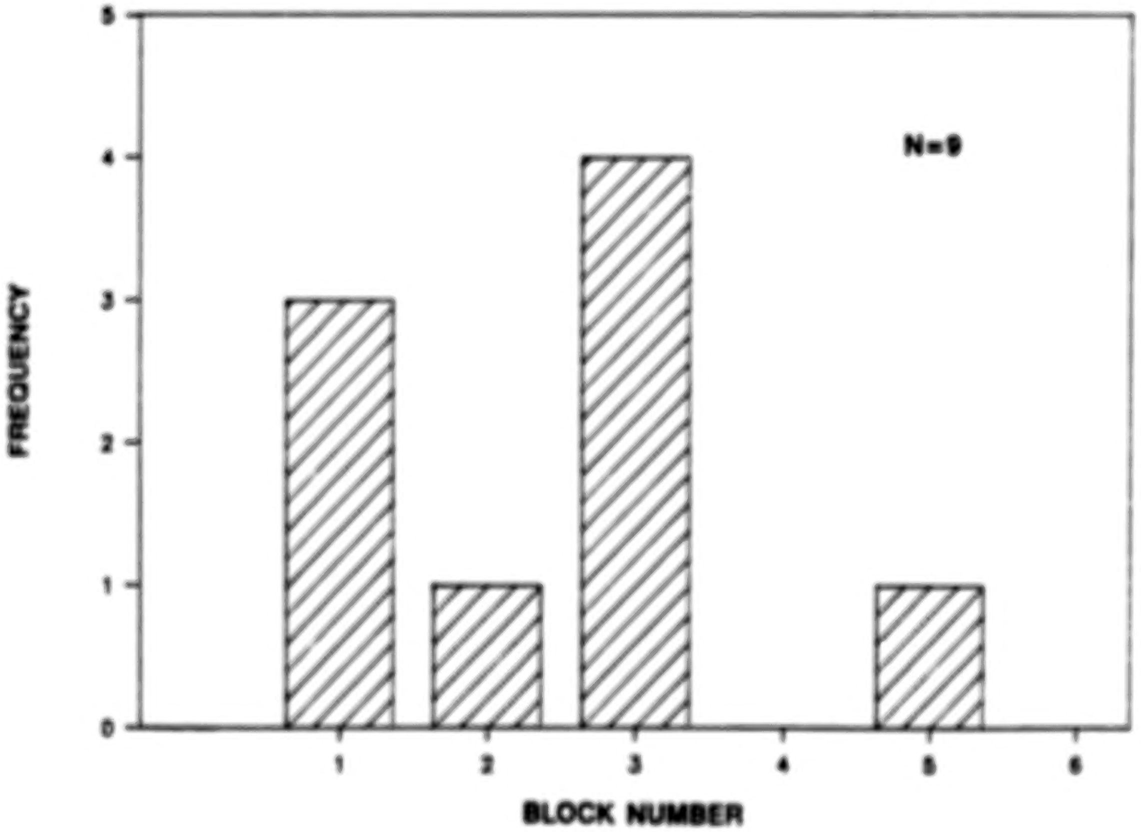
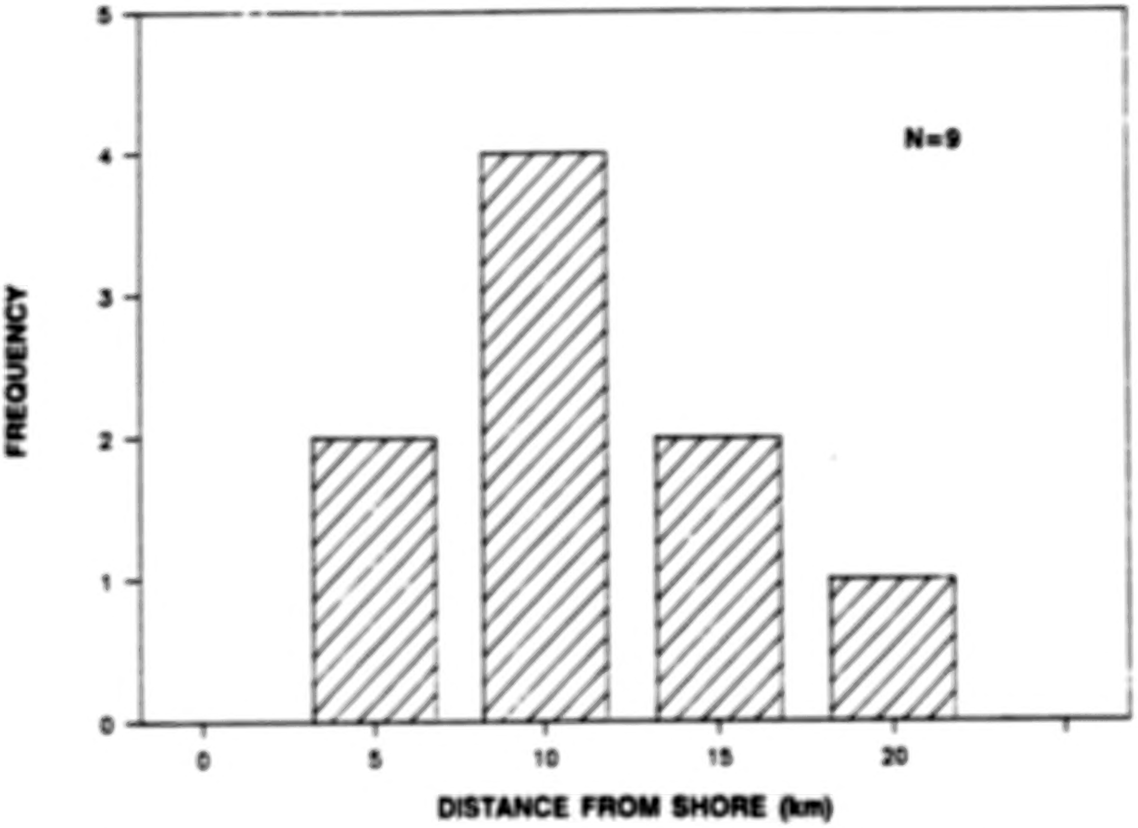


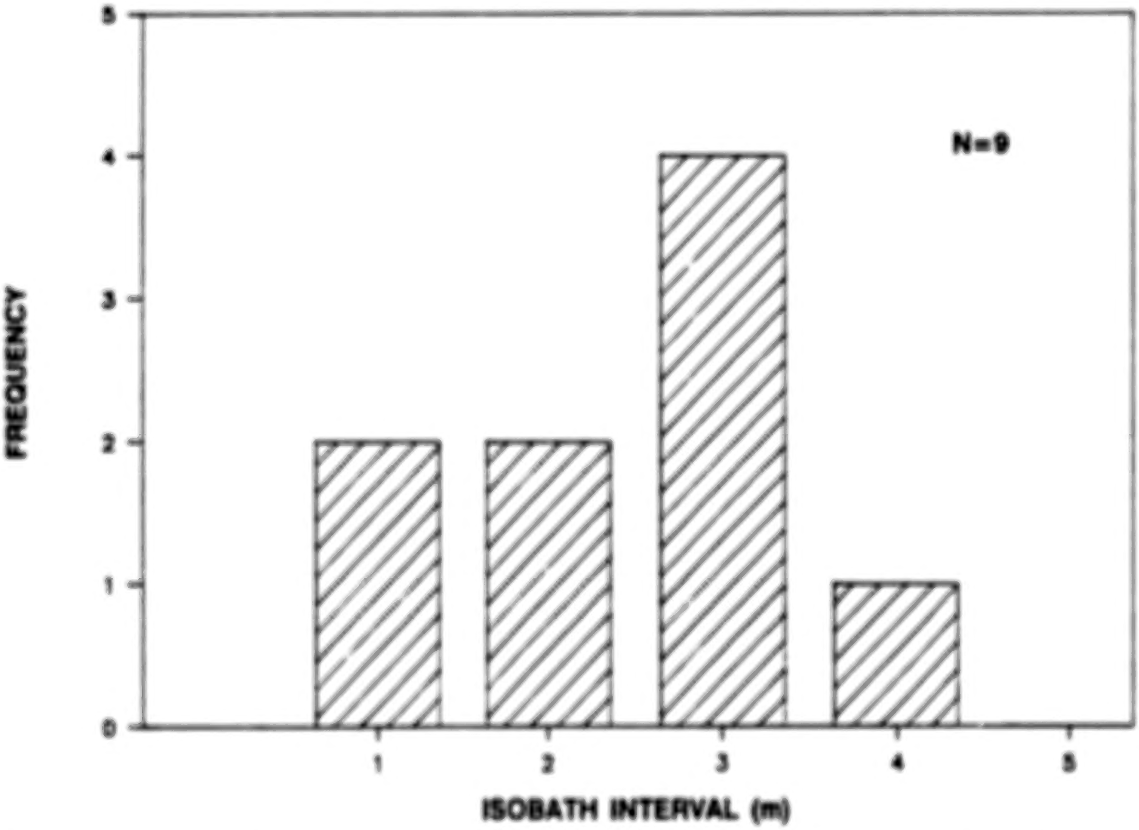
Appendix D-15. Numbers of gray whales as a function of water depth, northbound, Phase A migration.



Appendix D-16. Number of cow/calf pairs as a function of block number, northbound, Phase B migration.



Appendix D-17. Number of cow/calf pairs as a function of distance from shore, northbound, Phase B migration.



Appendix D-18. Number of cow/calf pairs as a function of water depth, northbound, Phase B migration.

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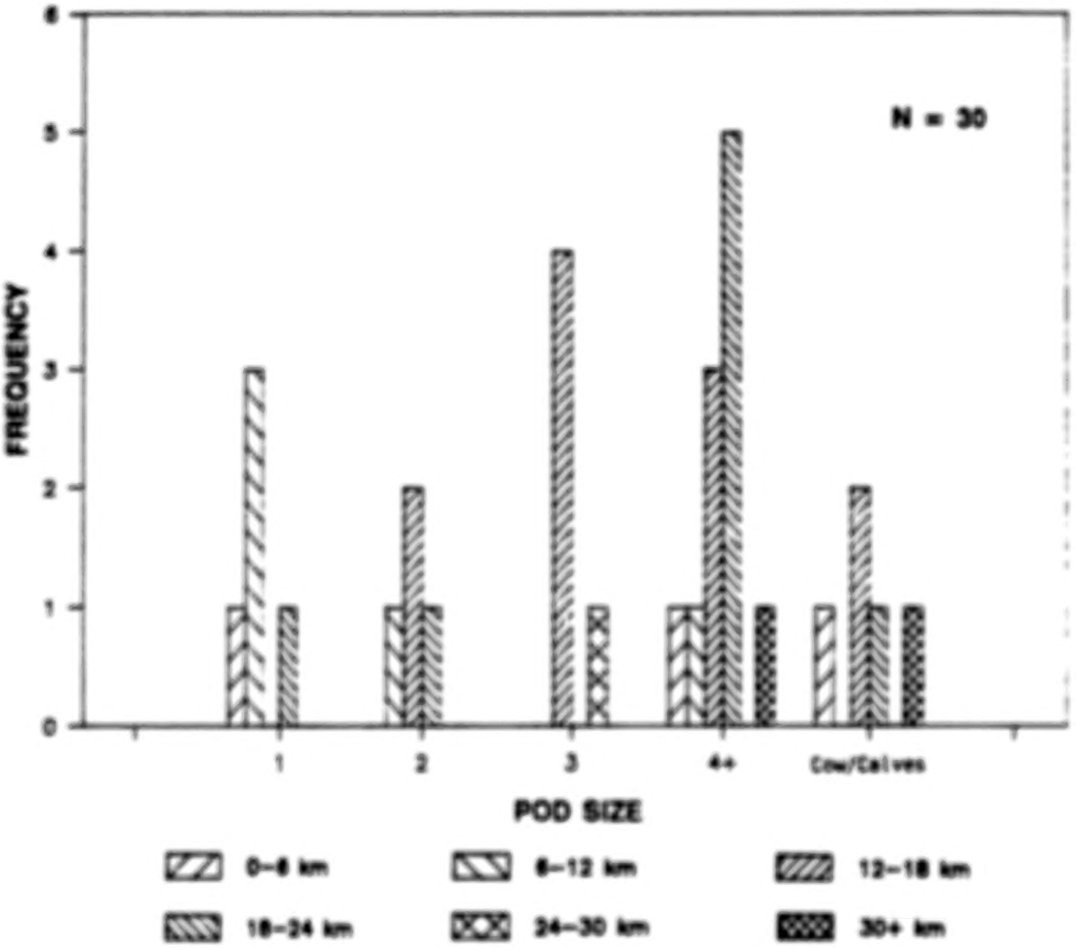
Appendix D-19. Densities of non-cow/calf pairs as a function of distance from shore, southbound migration.

Block	Distance Intervals (km)	No. of Whales	Total Survey Density (n/km²)	Total Area (km²)
a) Whales/km²				
1	3.2- 6.4	5	0.013	385.28
2	6.4- 9.6	8	0.021	385.28
3	9.6-12.8	10	0.026	385.28
4	12.8-16.0	21	0.055	385.28
5	16.0-19.2	16	0.042	385.28
6	19.2-28.6	22	0.029	770.56
7	28.6-32.0	4	0.005	770.56
Total		86	0.189	3467.52
Mean			0.027	866.88
S.D.			0.017	
b) Pods/km²				
1	3.2- 6.4	1	0.003	385.28
2	6.4- 9.6	3	0.008	385.28
3	9.6-12.8	4	0.010	385.28
4	12.8-16.0	7	0.018	385.28
5	16.0-19.2	4	0.010	385.28
6	19.2-28.6	5	0.006	770.56
7	28.6-32.0	1	0.001	770.56
Total		25	0.057	3467.52
Mean			0.007	866.88
S.D.			0.006	

Appendix D-20. Densities of southbound cow/calf pairs as a function of distance from shore, southbound migration.

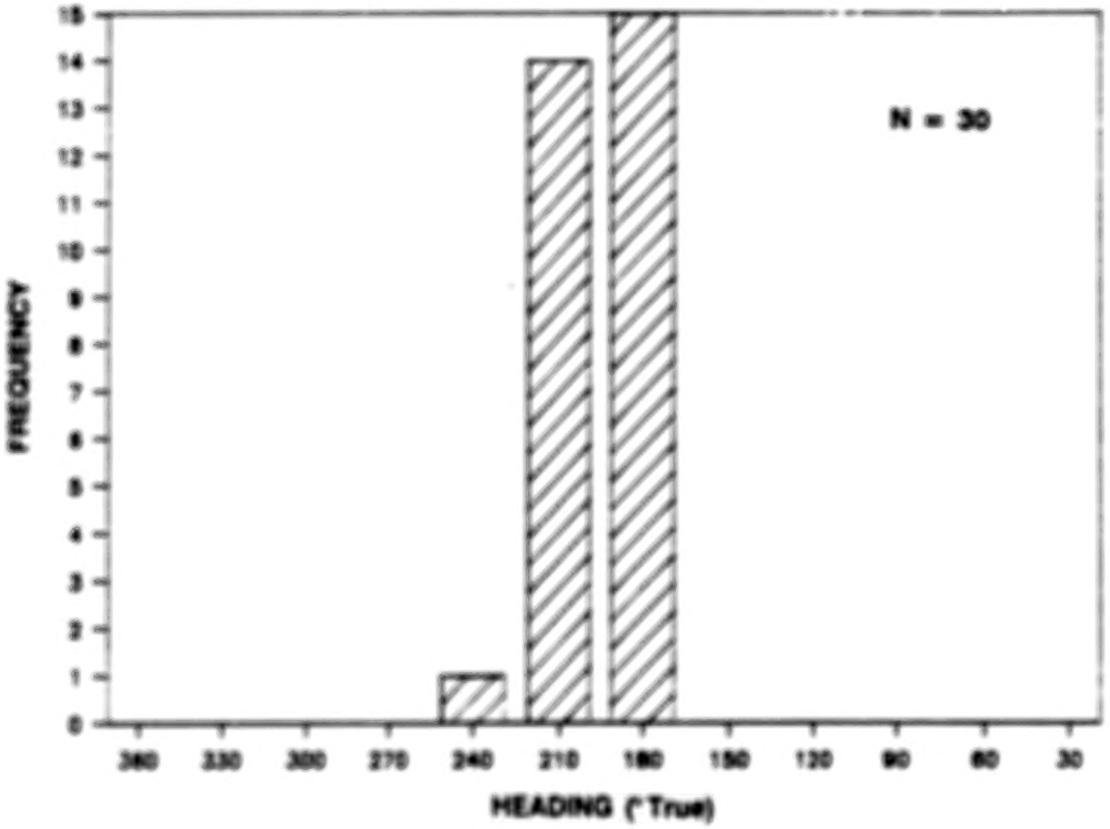
Block	Distance Intervals (km)	No. of Whales	Total Survey Density (n/km²)	Total Area (km²)
a) Whales/km²				
1	3.2- 6.4	2	0.005	385.28
2	6.4- 9.6	0	0.000	385.28
3	9.6-12.8	2	0.005	385.28
4	12.8-16.0	3	0.008	385.28
5	16.0-19.2	0	0.000	385.28
6	19.2-28.6	4	0.005	770.56
7	28.6-32.0	2	0.003	770.56
Total		13	0.026	3467.52
Mean			0.004	866.88
S.D.			0.003	
b) Pods/km²				
1	3.2- 6.4	1	0.003	385.28
2	6.4- 9.6	0	0.000	385.28
3	9.6-12.8	1	0.003	385.28
4	12.8-16.0	1	0.003	385.28
5	16.0-19.2	0	0.000	385.28
6	19.2-28.6	1	0.001	770.56
7	28.6-32.0	1	0.001	770.56
Total		5	0.010	3467.52
Mean			0.001	866.88
S.D			0.001	



Appendix D-21. Distribution of gray whale pods and individuals as a function of distance from shore, southbound migration.

Appendix D-22. Distribution of gray whale pods and individuals as a function of distance from shore, southbound migration.

	Pods			Whales			
	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Distance (km)				**Non-Cow/Calves**			
0	0	0.0	0.0	0	0.0	0.0	0.0
0-2	0	0.0	0.0	0	0.0	0.0	0.0
2-4	0	0.0	0.0	0	0.0	0.0	0.0
4-6	1	4.0	4.0	5	5.8	5.8	5.0
6-8	1	4.0	8.0	2	2.3	8.1	2.0
8-10	1	4.0	12.0	1	1.2	9.3	1.0
10-12	1	4.0	16.0	5	5.8	15.1	5.0
12-14	3	12.0	28.0	8	9.3	24.4	2.7
14-16	3	12.0	40.0	10	11.6	36.0	3.3
16-18	6	24.0	64.0	18	20.9	57.0	3.0
18-20	1	4.0	68.0	4	4.7	61.6	4.0
20-22	3	12.0	80.0	11	12.8	74.4	3.7
22-24	2	8.0	88.0	14	16.3	90.7	7.0
24-26	1	4.0	92.0	3	3.5	94.2	3.0
26-28	1	4.0	96.0	1	1.2	95.3	1.0
28-30	0	0.0	96.0	0	0.0	95.3	0.0
30-32	1	4.0	100.0	4	4.7	100.0	4.0
All Data	25	100.0		86	100.0		3.4
Distance (km)				**Cow/Calves**			
0	0	0.0	0.0	0	0.0	0.0	0.0
0-2	0	0.0	0.0	0	0.0	0.0	0.0
2-4	0	0.0	0.0	0	0.0	0.0	0.0
4-6	1	20.0	20.0	2	15.4	15.4	2.0
6-8	0	0.0	20.0	0	0.0	15.4	0.0
8-10	0	0.0	20.0	0	0.0	15.4	0.0
10-12	0	0.0	20.0	0	0.0	15.4	0.0
12-14	1	20.0	40.0	2	15.4	30.8	2.0
14-16	1	20.0	60.0	2	15.4	46.2	2.0
16-18	0	0.0	60.0	0	0.0	46.2	0.0
18-20	0	0.0	60.0	0	0.0	46.2	0.0
20-22	0	0.0	60.0	0	0.0	46.2	0.0
22-24	1	20.0	80.0	3	23.1	69.2	3.0
24-26	0	0.0	80.0	0	0.0	69.2	0.0
26-28	0	0.0	80.0	0	0.0	69.2	0.0
28-30	0	0.0	80.0	0	0.0	69.2	0.0
30-32	1	20.0	100.0	4	30.8	100.0	4.0
All Data	5	100.0		13	100.0		2.6



Appendix D-23. Headings of gray whales, southbound migration.

Appendix D-24. Numbers of all northbound gray whales by pod size, individuals, and migration phase, extralimitals included.

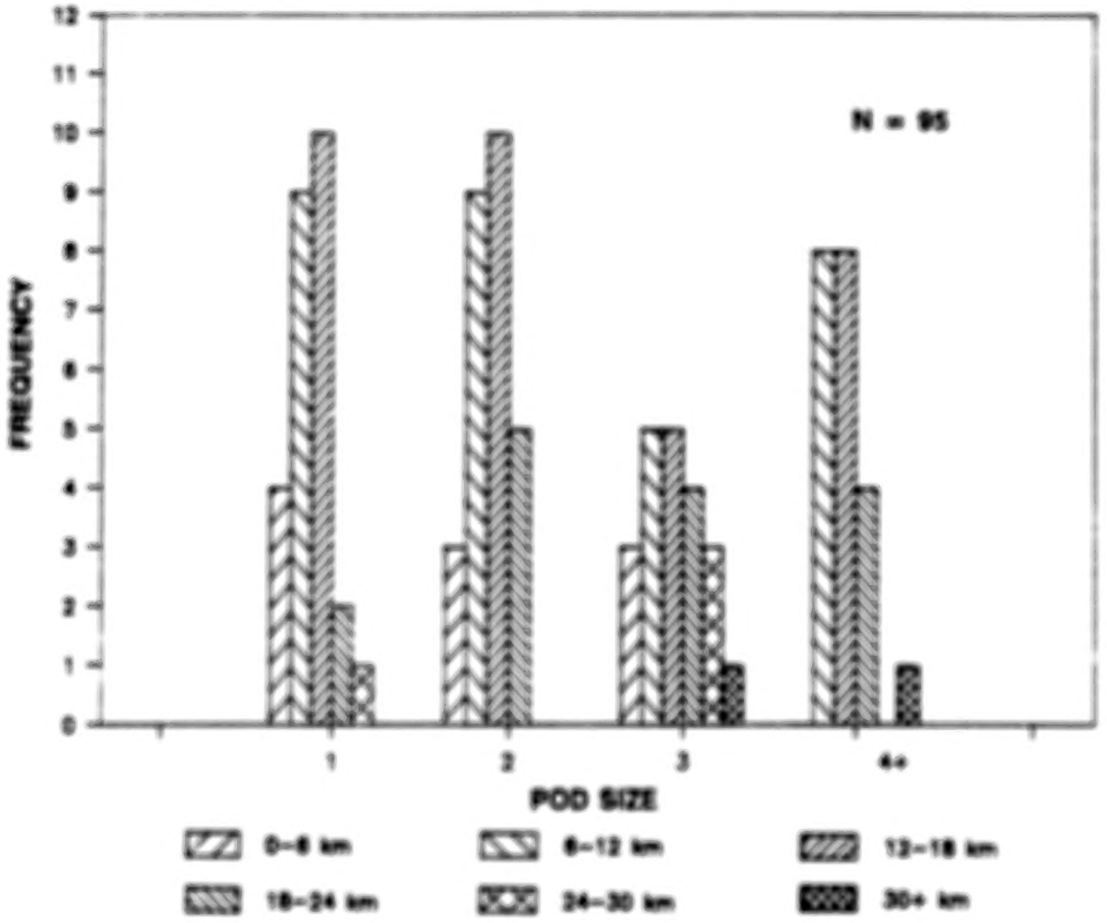
	Pods			Whales		
Pod Size	n	% By Phase	% By Animals	n	% By Phase	% By Animals
Phase A						
1	36	28.1	25.9	36	10.6	9.8
2	37	28.9	26.6	74	21.8	20.2
3	28	21.9	20.1	84	24.7	22.9
4	14	10.9	10.1	56	16.5	15.3
5	9	7.0	6.5	45	13.2	12.3
6	1	0.8	0.7	6	1.8	1.6
7	1	0.8	0.7	7	2.1	1.9
14	1	0.8	0.7	14	4.1	3.8
18	1	0.8	0.7	18	5.3	4.9
Subtotal	128	100.0	92.1	340	100.0	92.1
Phase B						
2	8	72.7	5.8	16	59.3	4.4
3	1	9.1	0.7	3	11.1	0.8
4	2	18.2	1.4	8	29.6	2.2
Subtotal	11	100.0	7.9	27	100.0	7.9
Non-Cow/Calves	-	-	-	355		96.7
Calves Only	-	-	-	12		3.3
All Northbound	139	100.0	100.0	367	100.0	100.0

Appendix D-25. Numbers of all northbound gray whales by pod size, individuals, and migration phase, extralimitals excluded.

	Pods			Whales		
Pod Size	n	% By Phase	% By Animals	n	% By Phase	% By Animals
Phase A						
1	26	27.4	24.8	26	10.2	9.3
2	27	28.4	25.7	54	21.3	19.4
3	21	22.1	20.0	63	24.8	22.6
4	10	10.5	9.5	40	15.7	14.3
5	8	8.4	7.6	40	15.7	14.3
6	1	1.1	1.0	6	2.4	2.2
7	1	1.1	1.0	7	2.8	2.5
14	0	0.0	0.0	0	0.0	0.0
18	1	1.1	1.0	18	7.1	6.5
Subtotal	95	100.0	90.5	254	100.0	91.0
Phase B						
2	7	70.0	6.7	14	56.0	5.0
3	1	10.0	1.0	3	12.0	1.1
4	2	20.0	1.9	8	32.0	2.9
Subtotal	10	100.0	9.5	25	100.0	9.0
Non-Cow/Calves	-	-	-	268		96.1
Calves Only	-	-	-	11		3.9
All Northbound	105	100.0	100.0	279	100.0	100.0

Appendix D-26. Densities of gray whales as a function of distance from shore, northbound, Phase A migration.

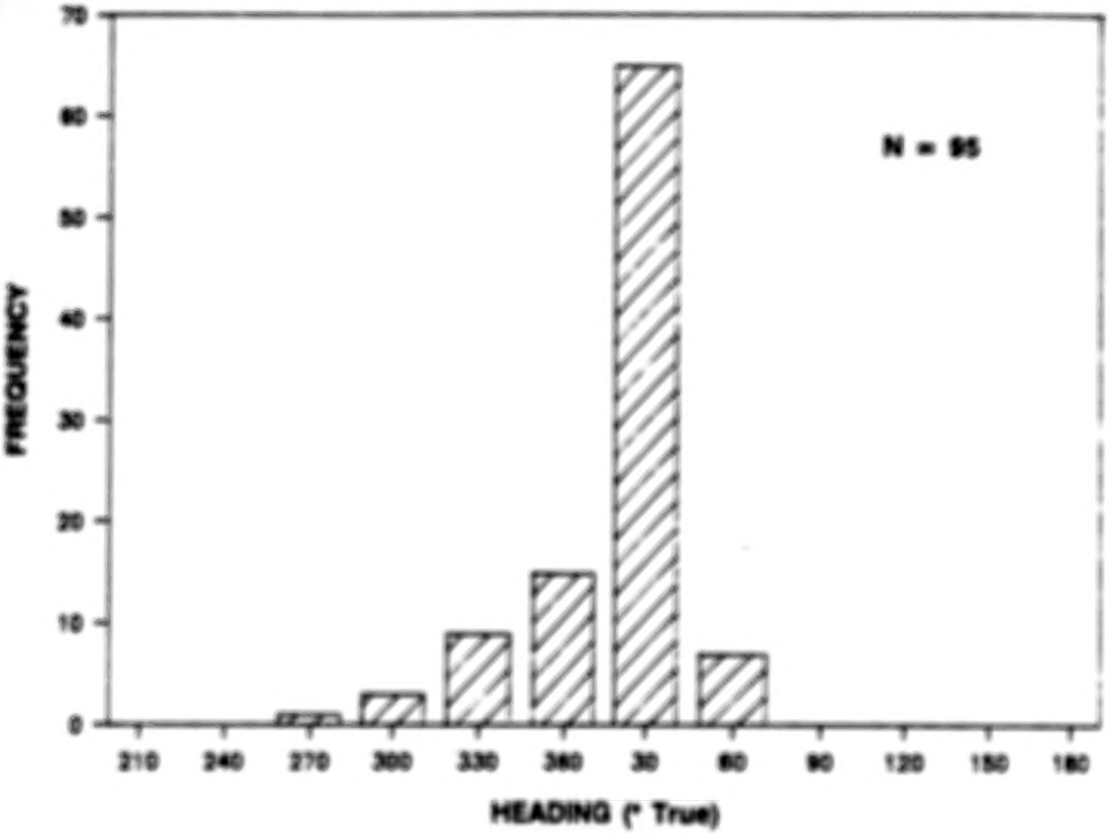
Block	Interval (km)	No. Observed	Density (km^2) Mean ± S.D.	No. of Surveys	Survey Density	Total Area (km^2)
a) **Whales/km^2**						
1	0- 3.2	4	0.002 ± 0.001	3	0.002	1857.6
2	3.2- 6.4	54	0.022 ± 0.017	3	0.029	1857.6
3	6.4- 9.6	32	0.014 ± 0.009	3	0.018	1754.4
4	9.6-12.8	50	0.022 ± 0.023	3	0.030	1651.5
5	12.8-16.0	39	0.022 ± 0.027	3	0.024	1651.5
6	16.0-19.2	46	0.022 ± 0.020	3	0.028	1651.5
7	19.2-28.6	11	0.003 ± 0.003	3	0.003	3302.4
8	28.6-32.0	18	0.004 ± 0.004	3	0.005	3302.4
Total		254	0.014 ± 0.016	24	0.015	17028.8
b) **Pods/km^2**						
1	0- 3.2	3	0.002 ± 0.001	3	0.002	1857.6
2	3.2- 6.4	20	0.009 ± 0.005	3	0.011	1857.6
3	6.4- 9.6	15	0.008 ± 0.002	3	0.009	1754.4
4	9.6-12.8	16	0.009 ± 0.005	3	0.010	1651.5
5	12.8-16.0	15	0.008 ± 0.010	3	0.009	1651.5
6	16.0-19.2	18	0.009 ± 0.008	3	0.011	1651.5
7	19.2-28.6	3	0.001 ± 0.001	3	0.001	3302.4
8	28.6-32.0	5	0.001 ± 0.001	3	0.002	3302.4
Total		95	0.006 ± 0.006	24	0.006	17028.8



Appendix D-27. Distribution of gray whale pods as a function of distance from shore, northbound, Phase A migration.

Appendix D-28. Distance from shore of gray whales and pods, northbound, Phase A migration.

	Pods			Whales			
	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Distance (km)							
0-2	0	0.0	0.0	0	0.0	0.0	0.0
2-4	4	4.2	4.2	6	2.4	2.4	1.5
4-6	6	6.3	10.5	13	5.1	7.5	2.2
6-8	5	5.3	15.8	16	6.3	13.8	3.2
8-10	15	15.8	31.6	39	15.4	29.1	2.6
10-12	11	11.6	43.2	23	9.1	38.2	2.1
12-14	8	8.4	51.6	21	8.3	46.5	2.6
14-16	11	11.6	63.2	37	14.6	61.0	3.4
16-18	14	14.7	77.9	36	14.2	75.2	2.6
18-20	10	10.5	88.4	26	10.2	85.4	2.6
20-22	2	2.1	90.5	6	2.4	87.8	3.0
22-24	3	3.2	93.7	12	4.7	92.5	4.0
24-26	1	1.1	94.7	1	0.4	92.8	1.0
26-28	2	2.1	96.8	6	2.4	95.3	3.0
28-30	1	1.1	97.9	3	1.2	96.5	3.0
30-32	1	1.1	98.9	3	1.2	97.6	3.0
32-34	1	1.1	100.0	6	2.4	100.0	6.0
Total	95	100.0		254	100.0		2.7



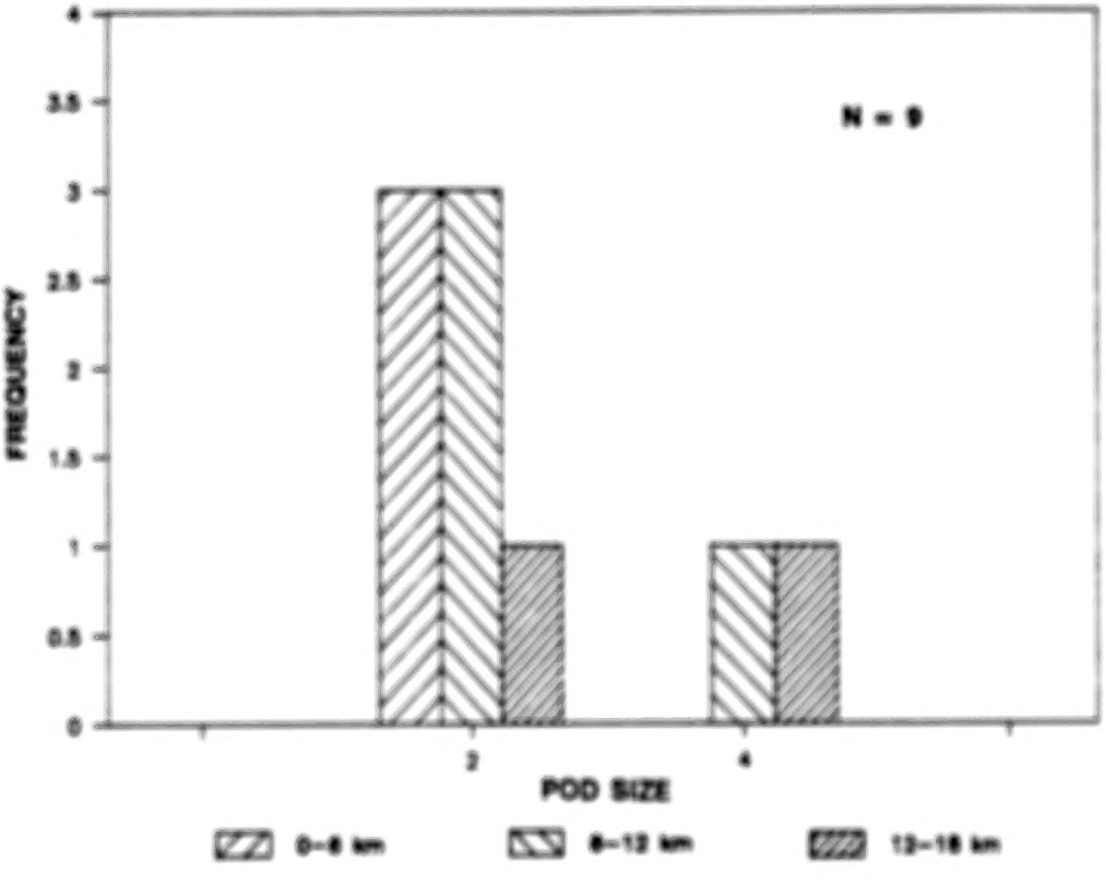
Appendix D-29. Frequency of headings of gray whale pods, northbound, Phase A migration.

Appendix D-30. Densities of gray whales and pods as a function of distance from shore, northbound, Phase B migration.

Block	Intervals (km)	No. Observed	Density (km²) Mean ± S.D.	No. of Surveys	Total Survey Density	Total Area (km²)
a) Whales/km²						
1	0- 3.2	6	0.015 ± 0.018	3	0.003	1857.6
2	3.2- 6.4	2	0.005 ± 0.006	3	0.001	1857.6
3	6.4- 9.6	11	0.007 ± 0.003	3	0.006	1754.4
4	9.6-12.8	0	0.000 ± 0.000	3	0.000	1651.5
5	12.8-16.0	4	0.004 ± 0.005	3	0.002	1651.5
6	16.0-19.2	0	0.000 ± 0.000	3	0.000	1651.5
7	19.2-28.6	0	0.000 ± 0.000	3	0.000	3302.4
8	28.6-32.0	0	0.000 ± 0.000	3	0.000	3302.4
Total		23	0.003 ± 0.008	24	0.001	17028.8
b) Pods/km²						
1	0- 3.2	3	0.005 ± 0.008	3	0.002	1857.6
2	3.2- 6.4	1	0.002 ± 0.003	3	0.001	1857.6
3	6.4- 9.6	4	0.003 ± 0.002	3	0.002	1754.4
4	9.6-12.8	0	0.000 ± 0.000	3	0.000	1651.5
5	12.8-16.0	1	0.000 ± 0.001	3	0.001	1651.5
6	16.0-19.2	0	0.000 ± 0.000	3	0.000	1651.5
7	19.2-28.6	0	0.000 ± 0.000	3	0.000	3302.4
8	28.6-32.0	0	0.000 ± 0.000	3	0.000	3302.4
Total		9	0.001 ± 0.010	24	0.001	17028.8

Appendix D-31. Densities of gray whales and pods by survey, northbound, Phase B migration.

		Number of Pods/km²		Number of Whales/km²	
Survey	Area (km²)	No. of Pods	Mean ± S.D.	No. of Whales	Mean ± S.D.
March 1987	5676.75	2	0.0004 ± 0.0011	7	0.002 ± 0.005
May 1987	2064.00	5	0.002 ± 0.005	10	0.006 ± 0.010
March 1988	9288.00	2	0.0002 ± 0.0005	6	0.001 ± 0.002
Survey Mean	5676.25	3	0.001 ± 0.001	7.7	0.003 ± 0.003
Pooled Data	17028.75	9	0.001 -	9	0.001 -



Appendix D-32. Distribution of gray whales by distance from shore and by pod size, northbound, Phase B migration.

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Appendix D-33. Incidental aerial observations of marine mammals other than gray whales.

Species		Number	Date	Bearing/Location	Behavior/ Magnetic Heading
Zalophus californianus		60	27 Apr 86	Platform Irene	Rafting
(California sea lion)		80	27 Apr 86	Platform Irene	Rafting
		18	4 May 86	Platform Irene	Rafting
	Total	156			
Balaenoptera acutorostrata		1	16 Mar 88	34 59 x 120 59	345
(Minke whale)					
Megaptera novaeangliae		1	26 Apr 86	34 52 x 120 43	355
(humpback whale)					
Delphinus delphis		40	14 Mar 88	34 44 x 120 50	165
(common dolphin)		250	16 Mar 88	34 47 x 120 46	265
		220	13 Mar 88	34 49 x 120 48	240
	Total	510			
Lagenorhynchus obliquidens		400*	4 May 86	34 45 x 120 46	300
(Pacific whitesided dolphin)		600*	4 May 86	34 50 x 120 44.5	330
		1000*	4 May 86	Platform Falcon	275
		2000*	4 May 86	Platform Falcon	270
		80	12 Mar 88	34 50 x 120 59	290
		150	14 Mar 88	34 56 x 120 51	310
		250	28 Mar 87	-	265
	Total	4480			
Tursiops truncatus		9	21 May 87	34 58 x 120 39	190
(Bottlenose dolphin)		13	21 May 87	35 01 x 120 38	285
		11	27 Mar 87	34 58 x 120 40	-
		8	27 Mar 87	35 02 x 120 38	-
		12	28 Mar 87	35 05 x 120 39	165
		7	29 Mar 87	35 10 x 120 44	270
		11	13 Mar 88	34 59 x 120 39	005
		5	15 Mar 88	34 49 x 120 38	180
	Total	76			
Phocoenoides dalli		3	4 May 86	34 59 x 120 41.5	275
(Dall's porpoise)		10	4 May 86	34 50 x 120 41.5	275
		4	4 May 86	34 50 x 120 43.0	160
		4	4 May 86	35 00 x 120 41.5	170
	Total	21			

* Minimum numbers; sightings occurred throughout study area

APPENDIX E

Shorebased Survey Data

Appendix E-1. Weather and sighting conditions during shorebased surveys.

Survey	Morning or Afternoon	Atmospheric[1] Code	% Cloud Cover	Average Visibility (km)	Beaufort[2] Sea State
April/May 1986					
30 April	Morning	1	20	5.5	2
	Afternoon	1	70	3.1	3
1 May	Morning	3	70	5.5	2
	Afternoon	1	10	3.1	3
2 May	Morning	2	0	3.1	3
	Afternoon	1	0	5.3	2
4 May	Morning	2	20	5.3	2
	Afternoon	1	10	2.8	3
5 May	Morning	1	10	1.1	4
	Afternoon	1	30	1.0	4
6 May	Morning	1	5	1.1	4
January 1987					
12 Jan	Morning	1	10	5.4	2
	Afternoon	3	80	5.0	3
17 Jan	Morning	1	30	7.5	1
	Afternoon	1	0	4.5	1
18 Jan	Morning	1	10	8.0	1
	Afternoon	1	5	8.0	1
19 Jan	Morning	0	0	6.0	1
	Afternoon	0	0	4.0	3
20 Jan	Morning	0	0	10.0	1
	Afternoon	0	0	6.0	1
21 Jan	Morning	1	10	11.5	1
	Afternoon	1	10	10.0	1
March 1987					
17 Mar	Morning	1	1	8.1	1
	Afternoon	1	1	8.1	2
18 Mar	Morning	1	0	3.2	2
	Afternoon	1	0	4.8	3
25 Mar	Morning	1	0	2.4	2
	Afternoon		no survey		
26 Mar	Morning	1	0	4.8	2
	Afternoon	1	2	4.8	3
27 Mar	Morning	0	2	4.5	2
	Afternoon	1	1	9.2	3
28 Mar	Morning	1	0	12.1	1
	Afternoon	1	0	6.0	3
29 Mar	Morning	0	2	8.1	1
	Afternoon	0	5	8.1	3
May 1987					
5 May	Morning	1-2	50	0.8-2.5	2
	Afternoon		no survey		
6 May	Morning	1-2	50	2.4	1
	Afternoon		no survey		
11 May	Morning	2	100	0.0-2.5	1
	Afternoon		no survey		
12 May	Morning	2	100	0.0-4.8	1
	Afternoon	1-2	50	5.6	2

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[1] 0 = clear; 1 = haze; 2 = fog; 3 = cloudy

[2] On the Beaufort scale of 0 to 12, calm to hurricane

Appendix E-1 (Cont).

Survey State	Morning or Afternoon	Atmospheric Code	% Cloud Cover	Average Visibility (km)	Beaufort Sea
		March 1988			
6 March	Morning	1	20	5.2	3
	Afternoon		no survey		
7 March	Morning	0	5	4.0	3
	Afternoon	1	5	3.2	4
8 March	Morning	1	9	4.4	0
	Afternoon	1	30	5.6	2
9 March	Morning	0	5	4.8	3
	Afternoon				
10 March	Morning	0	0	5.6	3
	Afternoon	1			
11 March	Morning	0	0	5.3	2
	Afternoon	1			
12 March	Morning	0	0	7.7	2
	Afternoon	0	0	8.0	2
14 March	Morning	0	0	7.2	2
	Afternoon	0			
15 March	Morning	2	100	2.8	2
	Afternoon	1-2	100	3.2	4
16 March	Morning	1-2	75	2.6	1
	Afternoon	1	10	2.4	5
17 March	Morning	1-2	0	4.8	2
	Afternoon	1	0	3.2	2
18 March	Morning	0	0	4.8	1
		April 1988			
18 April	Morning	3	100	4.2	3
	Afternoon	3	40	4.8	2
25 April	Morning	0	0	4.8	2
	Afternoon	1	0	4.5	3
26 April	Morning	2	100	0.0-3.7	2
	Afternoon	0	50	4.0	2
27 April	Morning	3	100	3.2	2
	Afternoon	2	100	4.8	2
28 April	Morning	2	95	4.8	1

Appendix E-2. Grey whale sighting information, April/May 1986.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Shorebased sighting information, April-May 1986							
30 Apr 1986	0907-1740	10	19	1.9	8.4	1.2	2.3
1 May 1986	0713-1620	7	16	2.3	6.5	1.1	2.5
2 May 1986	0908-1725	16	36	2.3	7.8	2.1	4.6
4 May 1986	0729-1519	5	12	2.4	7.2	0.7	1.7
5 May 1986	0721-1443	7	16	2.3	7.1	1.0	2.3
6 May 1986	0730-1101	3	6	2.0	3.0	1.0	2.0
Survey Total		48	105	2.2	40.0	1.2	2.6
Non-Cow/Calves		2	2	1.0	40.0	0.1	0.1
Cow/Calves (Pairs)		40	80	2.0	40.0	1.0	2.0
1 Cow/2 Calves		1	3	3.0	40.0	0.0	0.1
Double Cow/Calves		5	20	4.0	40.0	0.1	0.5

a Summary of sightings as animals entered the study area prior to splitting and joining. Observatons made from Point Sal.

b Average sighting time for two observations sites for each day. Total of 80 hrs by two observation teams over the six survey days.

Pod Size	No. of Pods	% of Total	No. of Indv.	% of Total
b) April/May 1986 pod composition				
1	2	4.2	2	1.9
2	40	83.3	80	76.2
3	1	2.1	3	2.9
4	5	10.4	20	19.0
Total	48	100.0	105	100.0

Appendix E-3. Gray whale sighting information, January 1987.

Date	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Shorebased sighting information, January 1987.						
12 Jan 1987	5	7	1.4	1.7	2.9	4.1
17 Jan 1987	8	12	1.5	4.1	2.0	2.9
18 Jan 1987	12	26	2.2	6.6	1.8	3.9
19 Jan 1987	6	7	1.2	4.2	1.4	1.7
20 Jan 1987[a]	23	41	1.8	8.3	2.8	4.9
21 Jan 1987[b]	16	38	2.4	6.3	2.5	6.0
Survey Total	70	131	1.9	31.2	2.2	4.2
Non-Cow/Calves (Pairs)	67	125	1.9	31.2	2.1	4.0
Cow/Calves (Pairs)	3	6	2.0	31.2	0.1	0.2

a =2 cow/calves (pairs)

b =1 cow/calf (pair)

Pod Size	No. of Pods	% of Total	No. of Indv.	% of Total
b) January 1987 pod composition				
1	32	45.7	32	24.4
2	18	25.7	36	27.5
3	14	20.0	42	32.1
4	1	1.4	4	3.1
5	1	1.4	5	3.8
6	1	1.4	6	4.6
Cow/Calves (Pairs)	3	4.3	6	4.6
Total	70	100.0	131	100.0

Appendix E-4. Gray whale sighting information, March 1987.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Shorebased sighting information, March 1987							
17 Mar 1987	0827-1219	6	10	1.7	5.8	1.0	1.7
25 Mar 1987	0813-1235	4	9	2.3	4.6	0.9	2.0
26 Mar 1987	0709-1336	4	14	3.5	6.5	0.6	2.2
27 Mar 1987	0735-1324	5	10	2.0	5.9	0.8	1.7
28 Mar 1987	0725-1402	8	14	1.8	7.0	1.1	2.0
29 Mar 1987	1109-1225	2	3	1.5	1.3	1.5	2.3
Survey Total		29	60	2.1	31.1	0.9	2.0

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
b) March 1987 pod composition.				
1	10	34.5	10	16.7
2	14	48.3	28	46.7
3	2	6.9	6	10.0
4	2	6.9	8	13.3
8	1	3.4	8	13.3
Total	29	100.0	60	100.0

Appendix E-5. Gray whale sighting information, March 1988.

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Shorebased sighting information, March 1988							
6 Mar 1988	0907-1131	4	5	1.3	2.4	1.7	2.1
7 Mar 1988	0848-1252	8	9	1.1	4.1	2.0	2.2
8 Mar 1988	0752-1702	20	30	1.5	9.2	2.2	3.3
9 Mar 1988	0709-1026	5	5	1.0	3.3	1.5	1.5
10 Mar 1988	0723-1021	8	13	1.6	2.9	2.8	4.5
11 Mar 1988	0651-1233	11	20	1.8	5.7	1.9	3.5
12 Mar 1988	0739-1638	20	33	1.7	9.0	2.2	3.7
14 Mar 1988	0655-1116	8	9	1.8	4.4	1.8	2.0
15 Mar 1988	0758-1252	5	7	1.4	4.9	1.0	1.4
16 Mar 1988	0649-1345	7	10	1.4	6.9	1.0	1.4
17 Mar 1988	0714-1412	16	23	1.4	7.0	2.3	3.3
18 Mar 1988	0625-1051	11	16	1.5	4.4	2.5	3.6
Survey Total		123	180	1.5	64.2	1.9	2.8

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
b) Pod Composition, all data				
1	76	61.8	76	42.2
2	39	31.7	78	43.3
3	6	4.9	18	10.0
4	2	1.6	8	4.4
Survey Total	123	100.0	180	100.0

Appendix E-6. Gray whale sighting information, April 1988

Date	Local Time	No. Sightings	No. Whales	Mean Pod Size	Observ. Time (hrs)	Number Sightings/hr	Number of Whales/hr
a) Shorebased sighting information, April 1988							
18 Apr 1988[a]	0848-1522	3	5	1.7	6.7	0.4	0.7
25 Apr 1988[b]	0726-1400	1	2	2.0	7.6	0.1	0.3
26 Apr 1988	0620-1012	0	0	0.0	8.3	0.0	0.0
27 Apr 1988[c]	0635-1602	8	12	1.5	9.5	0.8	1.3
28 Apr 1988	0648-0947	3	4	1.3	2.1	1.4	1.9
Survey Total		15	23	1.5	34.2	0.4	0.8
Cow/Calves (Pairs)		4	8	2.0	34.2	0.1	0.2
Non-Cow/Calves		11	15	1.4	34.2	0.3	0.4

a =1 Cow/Calf
b =2 Cow/Calves
c =3 Cow/Calves

Pod Size	No. of Pods	% of Total	No. of Whales	% of Total
b) Pod Composition, all data				
1	7	46.7	7	30.4
2	4	26.7	8	34.8
Cow/Calves (Pairs)	4	26.7	8	34.8
Total	15	100.1	23	100.0

Appendix E-7. Summary of all shorebased observations, southbound migration.

Date	Pod I.D.	No. Ind.	Track Time (min)	Speed (km/hr) Mean	s.d.	n	Headings (true north) Mean	s.d.	n	Distance Offshore (km)
South Migration 1987										
12JAN87	S1	1	18.2	10.9	0.2	2	191.4	30.7	2	5.0
	S4	2	35.7	7.7	3.7	4	160.7	57.6	4	2.3
	S5	1	11.8							
17JAN87	S7	1	27.0	5.3	1.0	8	167.2	28.9	8	0.9
	S9	1	<10 min							4.4
	S10	2	26.4	5.8	1.0	7	157.8	18.6	7	3.1
	S11	1	57.4	4.3	1.8	4	202.4	62.8	3	2.9
	S12	1	31.2	7.4	1.0	3	216.2	65.7	4	4.0
	S14	3	16.8	7.9	2.3	6	160.0	13.7	6	0.8
	S15	2	<10 min				165.2	52.2	2	2.9
18JAN87	S16	3	<10 min				129.1		1	5.8
	S17	3	22.1	16.6	8.4	6	134.7	40.4	6	6.4
	S19	2	22.4	4.5	0.6	3	144.1	6.4	3	4.4
	S20	1	26.0				160.5		1	4.2
	S22	1	40.5	7.1	5.0	4	193.3	22.3	4	5.6
	S23	1	14.5				144.8		1	8.4
	S24	2	25.8				219.8	60.2	2	6.4
	S25	1	<10 min				121.2		1	7.6
	S26	1	10.0				152.4		1	2.7
	S27	3	27.2	8.5	4.2	14	186.3	27.6	14	4.9
19JAN87	S28	1	33.0	8.0	3.1	9	163.8	15.0	9	2.6
	S29	1	16.8	7.7	3.1	8	174.7	44.1	8	0.8
	S30	1	12.8	6.9	0.4	8	180.0	19.0	8	0.7
	S31	2	<10 min	3.2	2.3	3	76.9	57.0	2	1.0
	S32	1	<10 min	7.1	0.8	6	207.0	23.4	6	0.4
	S33	1	11.0							4.4
20JAN87	S34	1	13.6	11.6	2.3	2	138.6	18.3	2	3.2
	S36	2	27.3	8.4	3.1	11	154.5	20.4	11	0.7
	S37	2	<10 min	9.2	4.7	11	152.3	52.1	14	5.5
	S38	3	24.0	4.3	2.1	6	165.9	45.2	6	5.9
	S39/40	3	<10 min				103.3		1	
	S42	1	<10 min	4.5	0.6	3	161.7	27.8	3	0.2
	S43	1	19.6	8.8	2.9	4	171.3	36.8	4	3.2
	S44	c/c	42.0	2.1	1.8	13	98.1	53.5	13	1.6
	S46	1	<10 min				169.3		1	0.8
	S47	1	22.0				96.8	64.6	3	5.4
	S48	1	19.2	9.2	2.6	3	159.7	43.5	4	7.5
	S50	c/c	23.8	6.4	2.3	11	136.7	11.9	10	2.1
	S52	1	<10 min				155.5		1	0.6
	S54	1	40.6	3.5	1.9	8	144.5	41.5	8	1.5
	S55	3	45.0	6.1	1.0	9	153.9	28.5	9	1.3
	S56	3	12.8	9.5	6.1	7	165.4	55.8	8	9.7
	S58	5	<10 min	11.4	6.6	3	138.3	50.0	3	10.1
	S59	3	<10 min				166.4		1	7.9
21JAN87	S60	3	15.3	4.2	4.2	4	132.7	29.1	2	
	S61	2	16.9	8.7	3.5	6	197.2	54.8	7	5.4
	S62	2	14.4	2.3	1.9	4	113.1	71.9	5	0.3
	S63	3	45.6	8.0	6.3	17	161.5	68.5	18	4.0
	S64	3	17.5				157.3		1	10.3
	S65	2	16.2	6.3	5.3	7	207.5	54.7	8	5.6
	S68	4	16.0	7.4	4.5	10	180.6	64.2	11	5.7
	S69	1	18.4	7.1	3.5	9	177.6	30.5	10	4.7
	S70	2	41.4	4.8	3.2	13	167.3	58.7	14	0.6
	S71	3	53.3	6.8	2.1	37	181.3	27.3	37	1.0
	S72	2	37.4	6.9	4.0	8	176.5	53.9	8	3.7
	S73	3	68.0	6.0	4.7	19	169.3	70.7	20	3.0
	S74	c/c	28.0	6.4	3.5	7	159.9	67.9	8	1.8
	S75	2	15.2							

Appendix E-7 (Cont).

Date	Pod I.D.	No. Ind.	Track Time (min)	Respiration (blows/hr)	DIVE TIMES Short Mean	s.d.	n	DIVE TIMES Long Mean	s.d.	n	DIVE TIMES All Mean	s.d.	n
South Migration 1987													
12JAN87	W1	1	18.2	27.3				2.5	1.1	7	2.5	1.1	7
	W4	2	35.7	22.2	0.5	0.2	11	5.0	2.9	6	2.1	2.8	17
	W5	1	11.8	15.0				5.9	2.3	2	5.9	2.3	2
17JAN87	W7	1	27.0	30.0	0.5	0.3	8	3.2	2.2	7	1.8	2.0	15
	W9	1	<10 min										
	W10	2	26.4	19.4	0.4	0.1	4	3.6	2.2	7	2.4	2.4	11
	W11	1	57.6	21.4	0.3	0.2	8	6.9	2.3	8	3.6	3.7	16
	W12	1	31.2	10.7	0.6	0.3	5	3.6	2.2	8	2.4	2.3	13
	W14	3	16.8	33.3	0.6	0.1	8	3.0	3.1	4	1.4	2.1	12
	W15	2	<10 min										
18JAN87	W16	3	<10 min										
	W17	3	22.1	26.1	0.5	0.3	11	2.9	2.0	6	1.3	1.7	17
	W19	2	22.4	22.2	0.8	0.1	3	4.0	2.3	5	2.8	2.4	8
	W20	1	26.0	14.0				5.2	1.3	5	5.2	1.3	5
	W22	1	40.5	26.1	0.6	0.3	4	3.4	2.2	11	2.7	2.3	15
	W23	1	14.5	25.0	0.3	0.2	2	4.7	1.3	3	2.9	2.4	5
	W24	2	25.8	16.2	1.0	0.3	2	6.0	2.8	4	4.3	3.3	6
	W25	1	<10 min										
	W26	1	10.0	26.1	0.9		1	3.1	1.1	3	2.5	1.4	4
	W27	3	27.2		0.5	0.2	15	3.2	1.9	6	1.3	1.6	21
19JAN87	W28	1	33.0	25.0	0.8	0.1	2	2.4	1.1	13	2.2	1.1	15
	W29	1	16.8	18.2	0.6	0.1	2	2.6	1.5	6	2.1	1.5	8
	W30	1	12.8	42.9				1.6	0.2	8	1.6	0.2	8
	W31	2	<10 min										
	W32	1	<10 min										
	W33	1	11.0		0.3	0.2	4	10.0		1	2.2	3.9	5
20JAN87	W34	1	13.6	13.3				6.8	0.3	2	6.8	0.3	2
	W36	2	27.3	15.4	0.8		1	2.2	0.8	12	2.1	0.9	13
	W37	2	<10 min		0.4	0.2	5	2.7	1.9	16	2.1	1.9	21
	W38	3	24.0	14.6	0.3	0.2	11	4.2	1.2	5	1.5	1.9	16
	W37/40	3	<10 min										
	W42	1	<10 min										
	W43	1	17.6	11.8	0.7		1	6.3	1.5	3	4.9	2.8	4
	W44	c/c	42.0	10.2	0.5	0.2	10	3.6	1.5	10	2.0	1.9	20
	W46	1	<10 min										
	W47	1	22.0	42.9	0.4	0.3	7	4.8	2.8	4	2.0	2.7	11
	W48	1	19.2	21.4	0.2	0.1	2	4.8	2.2	4	3.2	2.8	6
	W50	c/c	23.8	18.1	0.6	0.2	9	2.3	1.6	8	1.4	1.4	17
	W52	1	<10 min										
	W54	1	40.6	22.2	0.4	0.2	7	5.5	1.3	7	2.9	2.7	14
	W55	3	45.0	9.5	0.4	0.2	4	4.0	2.8	11	3.0	2.8	15
	W56	3	12.8	46.2	0.4	0.2	10	1.5	0.3	6	0.8	0.6	16
	W58	3	<10 min										
	W59	3	<10 min										
21JAN87	W60	3	15.3	12.5	0.5	0.1	6	4.1	2.0	3	1.7	2.1	9
	W61	2	16.9	22.2	0.4	0.2	5	2.1	0.9	7	1.4	1.1	12
	W62	2	14.4	16.7	0.3	0.1	3	4.5	0.6	3	2.4	2.2	6
	W63	3	45.6	22.2	0.5	0.2	29	3.7	1.9	9	1.2	1.7	38
	W64	3	17.5	9.0	0.6	0.3	4	5.1	2.9	3	2.5	2.9	7
	W65	2	16.2	21.5	0.3	0.1	4	3.1	2.0	5	1.8	2.0	9
	W68	4	16.0	24.0	0.6	0.2	14	3.8	0.8	2	1.0	1.1	16
	W69	1	18.4	26.1	0.7	0.2	4	3.9	1.1	4	2.3	1.8	8
	W70	2	41.4	21.4	0.5	0.2	10	4.5	2.3	8	2.3	2.5	18
	W71	3	53.3	18.8	0.6	0.3	25	2.3	1.2	16	1.3	1.2	41
	W72	2	37.4	14.3	0.5	0.2	12	3.2	2.3	10	1.7	2.0	22
	W73	3	48.0	8.8	0.5	0.3	11	3.2	2.2	13	2.0	2.1	24
	W74	c/c	28.0	27.3	0.5	0.2	3	3.8	2.2	7	2.8	2.4	10
	W75	2	15.2	17.7	0.5	0.2	5	4.2	3.2	3	1.9	2.7	8

Appendix E-6. Summary of all shorebased observations, northbound, Phase A migration.

Date	Pod I.D.	No. Ind.	Track Time (min)	Speed (km/hr) Mean	s.d.	n	Headings (true north) Mean	s.d.	n	Distance Offshore (km)
North Migration (Phase A) 1986										
26MAR86	128	1	12.6	4.3	1.5	3	N/A			0.8
North Migration (Phase A) 1987										
17MAR87	1	2	48.3	5.8	4.9	15	342.8	49.1	15	1.4
	2	2	<10 min				181.4	69.4	2	4.4
	3	2	58.5	3.2	3.8	27	324.8	57.9	26	0.4
	4	2	<10 min				282.8	37.5	2	2.4
	5	2	14.3	2.1		1	262.1	19.7	2	0.4
	6	1	<10 min							0.7
25MAR87	1	2	<10 min							
	2	1	<10 min	1.9	1.8	3	344.4	40.6	3	6.9
	3	4	105.1	4.7	5.8	24	337.7	72.2	23	6.9
	4	1	<10 min	1.8		1	315.5	60.7	2	0.7
26MAR87	5	1	<10 min							
	6	8	39.2	11.7	11.7	33	27.8	27.2	33	9.8
	7	1	152.9	5.4	5.3	37	116.0	21.3	38	4.3
	8	2	<10 min							5.5
27MAR87	1	2	125.8	3.3	3.1	35	12.1	57.4	34	6.0
	2	2	43.2	4.4	4.8	17	56.6	49.3	18	2.5
	3	2	<10 min				4.6		1	1.0
	4	2	16.7	5.3	2.0	10	71.2	34.8	11	1.3
	5	2	<10 min							
28MAR87	1	2	44.9	6.2	5.0	12	355.3	39.7	12	4.8
	2	1	<10 min	2.6		1	74.4	80.6	2	5.2
	3	1	<10 min							9.8
	4	1	<10 min				267.1		1	6.3
	5	2	<10 min	9.7	5.5	5	337.3	37.1	6	6.0
	6	3	23.1	8.2	6.6	23	354.8	34.4	23	6.6
	7	2	<10 min				255.7		1	7.7
	9	1	<10 min				262.1		1	3.4
29MAR87	1	2	38.7	10.1	6.5	10	347.9	64.0	7	8.6
	2	1	24.7							
North Migration (Phase A) 1988										
6MAR88	202	2	34.4	9.5	11.0	3			3	4.6
	203	1	13.6	2.8		1			1	
	204	1	<10 min	2.8		1			1	
	205	1	<10 min	2.8		1			1	
7MAR88	206	2	23.7	4.9		1			1	
	207	1	<10 min	4.9		1			1	5.3
	208	1	15.7	4.9		1			1	
	209	1	<10 min	4.9		1			1	
	211	1	60.1	4.6	2.4	16	289.7	45.2	16	
	213	1	15.5	7.1	3.7	3	299.3	10.4	3	1.6
	214	1	<10 min	10.8		1	339.0	63.2	2	0.9
8MAR88	214a	1	31.9	5.5	1.1	16	316.4	13.5	16	2.0
	215	2	<10 min	1.6	1.6	2	11.5	0.1	2	3.6
	217	2	<10 min	4.6	0.0	2	330.4	9.8	2	6.0
	218	3	43.2	5.8	0.8	13	296.0	19.5	13	1.9
	219	1	10.8	3.7		1	34.5	69.3	1	1.1
	220	1	10.1	4.8		1			1	0.6
	221	1	17.3	4.9	2.7	5	278.4	18.5	5	0.8
	222	1	13.7	6.0	3.1	4	306.4	7.8	4	1.5
	223	3	37.0	5.5	0.5	5	315.4	37.4	5	1.4
	224	1	<10 min							0.8
	226	2	<10 min	13.2	4.7	2	257.7	8.0	2	1.4
	227	1	19.0	6.5	1.6	3	280.8	23.3	3	0.4
	228	2	15.4	5.1	4.7	3	200.3	80.5	3	
	229	1	<10 min	4.9		1	27.0	76.7	1	
	230	1	26.9	4.9		1			1	
	231	2	16.7	3.4	1.9	2	333.8	49.2	2	1.0
	232	1	14.1	5.2	1.0	2	303.4	19.5	2	0.8
9MAR88	233	1	23.9	5.0	1.2	3	287.4	31.2	3	0.5
	237	1	30.0	4.0	1.9	5	289.3	3.6	5	0.8
	238	1	25.8	7.4	2.5	4	293.3	25.0	4	1.2

Appendix E-8 (Cont).

Date	Pad I.D.	No. Ind.	Track Time (min)	Speed (km/hr) Mean	s.d.	n	Headings (true north) Mean	s.d.	n	Distance Offshore (km)
	239	1	<10 min	5.7	1.4	2	272.4	4.2	2	0.7
10MAR88	243	1	10.9	4.9		1			1	
	245	2	48.6	6.9	1.6	7	309.0	46.4	7	4.0
	246	1	16.9	7.9	6.4	6	327.3	42.9	6	1.3
	246a	4	43.8	3.3	3.3	10	304.8	57.9	10	1.9
	247	2	29.7	2.2	1.4	18	121.0	69.2	18	4.3
	248	1	11.9	6.3	2.4	3	322.2	17.1	3	2.0
11MAR88	249a	3	113.5	4.6	3.8	57	1.5	54.7	57	3.8
	251	1	<10 min							3.8
	252	1	<10 min							7.4
	253	1	35.0	4.2	2.2	11	22.0	30.1	11	0.7
	254	2	38.4	3.2	1.6	26	359.9	73.2	26	2.6
	255	2	13.3	3.1		1	34.8		1	2.1
	256	3	<10 min							6.7
	257	1	<10 min							6.5
	260	3	32.6	1.8	0.7	4	324.9	22.1	4	3.2
	261	2	31.9	9.2		1	269.4		1	3.5
	262	1	<10 min							
12MAR88	263	1	19.1	5.0	0.3	5	64.0	11.5	5	1.1
	263a	2	19.2	0.4	0.1	5	39.0	35.9	5	0.3
	264	2	10.4	4.4	1.6	5	330.1	23.5	5	3.3
	265	1	24.7	4.8		1	342.4		1	3.5
	266	2	13.3	2.8		1			1	
	267	1	<10 min							2.5
	268	2	20.2	5.3	2.1	7	15.6	38.9	7	2.3
	271	2	44.8	5.1	2.6	7	323.1	20.7	7	3.0
	272	2	<10 min	2.8		1			1	4.1
	273	2	24.8	5.4	5.2	13	21.2	44.5	13	4.6
	276	1	13.3	5.9	2.4	2	23.0	17.2	2	4.0
	277	4	11.8	3.5	3.6	7	31.5	61.3	7	5.9
	278	2	<10 min	5.2	1.0	2	42.6	3.7	2	6.0
	280	1	<10 min							11.6
	281	3	<10 min							6.9
	282	1	<10 min							7.4
	283	2	23.2	14.7	5.8	4	330.7	52.6	4	4.0
	284	2	34.6	6.6	7.3	5	316.0	52.7	5	3.3
14MAR88	285	4	21.7	6.4	3.6	6	345.8	11.0	6	4.2
	286	1	61.7	3.4	2.6	13	24.8	57.5	13	0.4
	287	1	<10 min	2.0	2.7	2	26.7		1	0.3
	289	2	42.5	5.5	4.6	22	139.0	71.4	22	3.8
	290	1	13.2	6.5	0.5	2	344.7	6.0	2	2.2
	292	1	24.8	4.4	3.7	17	328.7	75.2	17	3.9
15MAR88	293	1	23.5	6.1	0.4	2	282.0	16.0	2	1.0
	294	2	21.8	3.4		1	296.9		1	4.4
	295	2	30.6	6.1	1.8	7	286.8	23.9	7	1.4
	296	1	17.2	4.0	1.3	5	308.3	26.3	5	0.9
	297	1	<10 min	2.5	3.2	2	308.5		1	2.3
16MAR88	298	1	<10 min	6.0	0.3	3	303.0	0.4	3	0.9
	301	1	44.3	8.2	4.3	2	281.9	28.2	2	1.2
	302	2	11.8	7.1	1.5	5	266.6	26.1	5	1.4
	303	2	29.2	5.8	2.7	10	292.5	42.2	10	1.1
	304	2	68.7	1.3	1.8	14	292.6	67.9	14	0.6
17MAR88	305	1	<10 min	3.6	0.1	2	291.3	36.0	2	0.3
	306	1	12.7	7.4	5.0	5	286.9	18.6	5	1.6
	307	1	69.7	3.9	2.1	9	304.0	21.6	9	1.5
	309	2	32.2	5.8	1.8	11	289.9	11.2	11	2.2
	311	1	16.7	3.9	0.9	2	292.6	6.1	2	3.4
	312	1	11.1	8.6	6.5	3	289.8	15.1	3	2.4
	313	1	11.3	5.2		1	344.8		1	4.0
	314	1	34.4	5.8	2.9	12	300.4	18.0	12	3.5
	315	2	22.8	2.7	1.2	8	342.0	22.0	8	4.6
	316	2	66.4	4.0	1.5	13	290.7	16.5	13	1.9
	317	2	17.2	5.0	0.0	2	315.9	5.1	2	2.5
	318	3	32.1	4.7	0.5	10	309.4	10.4	10	0.9
	319	2	32.6	5.1	0.7	13	295.0	17.0	13	1.7
	320	1	18.0	2.2	0.2	2	323.3	8.8	2	2.5
	321	1	10.2	3.8	0.9	2	292.4	12.0	2	0.3
18MAR88	322	2	23.0	6.5	4.9	9	283.5	54.9	9	0.7
	323	2	<10 min	2.8	2.9	2	269.0	8.4	2	0.6
	324	2	23.7	4.9	1.8	4	296.0	27.3	4	1.9
	325	1	11.8	3.4		1	320.5		1	4.1

Appendix E-8 (Cont).

Date	Pod I.D.	No. Ind.	Track Time (min)	Speed (km/hr) Mean	s.d.	n	Headings (true north) Mean	s.d.	n	Distance Offshore (km)
	326	2	20.9	5.2	0.4	7	296.3	20.0	7	1.0
	327	1	<10 min							1.1
	328	1	<10 min	9.0	4.4	3	320.2	11.7	3	5.0
	329	1	<10 min							7.3
	330	2	10.1	4.9		1			1	4.7
	331	1	<10 min							
18APR88	332	1	59.6	5.9	1.1	9	341.4	9.2	9	2.0
27APR88	336	2	<10 min							3.6
	337	1	34.4	4.6	0.4	2	40.7	14.3	2	3.2
	339	1	19.5	2.2	0.8	3	348.2	41.3	3	4.4
	342	2	<10 min	10.1		1	4.0		1	
28APR88	343	1	43.8	2.8	2.1	6	96.9	31.8	6	
	343	2	<10 min							3.1
	344	1	21.8	5.6	2.3	2	45.9	79.1	2	5.7

Appendix E-6. Summary of all shorebased observations, northbound, Phase B migration.

Date	Pod I.D.	No. Ind.	Track Time (min)	Speed (km/hr) Mean	s.d.	n	Headings (true north) Mean	s.d.	n	Distance Offshore (km)
North Migration (Phase B) 1986										
30APR86	102	2	31.5	4.9	4.9	13	N/A	-	-	0.4
	103	2	14.0	3.9	1.9	6	N/A	-	-	0.2
	104	2	<10 min	3.9	2.3	4	N/A	-	-	0.3
	105	2	23.6	4.8	3.1	7	N/A	-	-	0.4
	106	2	38.4				N/A	-	-	
	107	2	31.0	3.9	1.8	9	N/A	-	-	0.4
	108	2	31.1	4.7	2.4	11	N/A	-	-	0.3
	109	2	39.1	6.1	4.0	12	N/A	-	-	0.4
	110	2	26.0	4.5	2.7	13	N/A	-	-	0.4
1MAY86	111	2	12.3	5.4	1.1	4	N/A	-	-	0.4
	112	2	40.8	6.2	3.4	15	N/A	-	-	0.3
	113	2	30.6	5.0	2.8	20	N/A	-	-	0.3
	114	2	<10 min	3.0	1.6	3	N/A	-	-	0.2
	115	4	90.2				N/A	-	-	0.2
	115a	2	24.1	5.0	4.4	8	N/A	-	-	0.6
	115b	2	16.5	5.3	3.7	22	N/A	-	-	0.5
	116	2	29.0	6.8	1.3	13	N/A	-	-	0.6
	117	2	12.8	5.2	1.1	5	N/A	-	-	0.2
2MAY86	118	2	64.2	5.0	2.4	11	N/A	-	-	1.2
	119	3	78.3	3.4	2.9	20	N/A	-	-	0.5
	120	2	48.2	4.9	3.8	23	N/A	-	-	0.6
	121	2	15.5	7.1	6.6	4	N/A	-	-	0.3
	122	2	37.6	7.2	7.6	15	N/A	-	-	0.7
	123	4	55.1	5.3	3.7	24	N/A	-	-	0.3
	124	4	44.3	4.5	1.3	28	N/A	-	-	0.4
	125	2	14.5	4.3	1.8	4	N/A	-	-	0.3
	126	2	14.2	3.7	0.6	3	N/A	-	-	0.3
	127	2	33.8	1.8	1.1	8	N/A	-	-	0.5
	129	2	18.8	4.5	3.1	5	N/A	-	-	0.6
	130	6	70.2	5.2	1.6	24	N/A	-	-	0.7
	130a	2	<10 min				N/A	-	-	0.3
4MAY86	131	2	99.8	3.7	3.6	38	N/A	-	-	0.2
	132	4	<10 min	3.1		1	N/A	-	-	0.3
	132a	4	63.9	6.3	8.2	26	N/A	-	-	
	133	4	20.1	5.1	2.3	11	N/A	-	-	0.5
	134	2	25.2	3.2	1.3	9	N/A	-	-	0.3
	135	2					N/A	-	-	0.4
	137	2	21.0	6.9	5.3	6	N/A	-	-	0.4
	138	4	25.8	3.9	2.6	15	N/A	-	-	0.7
	140	2	51.9	4.0	2.9	20	N/A	-	-	0.4
	142	4	50.7	6.1	5.5	28	N/A	-	-	
	145	2	28.6	5.8	6.0	7	N/A	-	-	0.5
	148	2	15.6	7.7	5.9	5	N/A	-	-	0.3
	149	2	<10 min	6.4	1.8	2	N/A	-	-	0.2
5MAY86	150	2	11.2	4.2	1.5	4	N/A	-	-	0.2
	150a	2	53.0	4.3	3.4	18	N/A	-	-	0.5
	151	2	16.7	4.9	2.2	6	N/A	-	-	0.3
	152	2	28.4	5.0	2.2	16	N/A	-	-	0.4
	153	2	13.9	5.5	6.2	4	N/A	-	-	0.2
	154	4	22.5	4.8	3.3	6	N/A	-	-	0.5
	155	4	58.9				N/A	-	-	
	158	2	30.6	2.8	2.9	7	N/A	-	-	0.3
6MAY86	160	2	111.9	3.5	3.5	41	N/A	-	-	0.6
	161	2	<10 min				N/A	-	-	0.2
	162	2	68.3	4.5	2.4	25	N/A	-	-	0.4
North Migration (Phase B) 1988										
18APR88	401	2	26.6	6.0	1.0	7	N/A	-	-	1.0
	402	2	35.5	6.7	3.8	7	N/A	-	-	0.4
25APR88	405	2	50.1	4.3	1.6	21	N/A	-	-	0.2
27APR88	407	2	71.0	4.2	1.8	21	N/A	-	-	0.3

Appendix E-4 (Cont).

Date	Pod I.D.	No. Ind.	Track Time (min)	Respiration (Blows/hr)	DIVE TIMES Short			DIVE TIMES Long			DIVE TIMES All		
					Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n
North Migration (Phase B) 1986													
30APR86	102	2	31.5		0.4	0.3	7	4.6	1.8	6	2.4	2.4	13
	103	2	16.0		1.0		1	3.0	1.1	5	2.7	1.2	6
	104	2	<10 min					2.7	0.5	3	2.7	0.5	3
	105	2	23.4					3.4	2.1	6	3.4	2.1	6
	106	2	38.4		0.9	0.2	4	3.6	0.9	7	2.6	1.5	11
	107	2	31.0		1.0		1	3.7	1.2	8	3.4	1.4	9
	108	2	31.1		0.7	0.1	4	3.5	1.1	8	2.6	1.6	12
	109	2	39.1		0.2	0.2	12	3.0	1.4	12	1.6	1.7	24
	110	2	26.0		0.4	0.3	4	3.0	1.1	9	2.2	1.4	13
1MAY86	111	2	12.3	34.1	0.5	0.1	3	2.7	0.5	4	1.8	1.2	7
	112	2	43.8		0.4	0.4	4	3.3	1.8	12	2.5	2.0	16
	113	2	39.4	76.9	0.3	0.2	25	3.3	2.0	10	1.1	1.7	35
	114	2	<10 min										
	115	4	80.2		0.8	0.1	5	3.2	2.1	27	2.8	2.1	32
	115a	2	26.1		0.2	0.2	3	3.3	1.2	7	2.4	1.7	10
	115b	2	16.5		0.5	0.3	19	1.4	0.4	5	0.7	0.5	24
	116	2	29.0	67.0	0.3	0.2	9	2.4	0.9	11	1.5	1.2	20
	117	2	12.8	32.9	0.4	0.1	4	3.7	1.9	3	1.8	2.1	7
2MAY86	118	2	64.2	24.6	0.5	0.0	3	5.3	2.4	8	4.0	2.0	11
	119	3	78.3	24.6	0.3	0.2	42	2.7	1.3	22	0.9	1.2	64
	120	2	48.2	29.1	0.5	0.3	8	2.9	1.9	15	2.1	1.9	23
	121	2	15.5		0.9		1	2.9	1.0	5	2.6	1.2	6
	122	2	37.4	18.6	0.5	0.2	5	3.2	0.7	13	2.3	1.9	18
	123	4	55.1	26.7	0.5	0.3	14	2.4	1.2	20	1.6	1.3	34
	124	4	64.3	33.9	0.4	0.2	38	1.8	0.7	16	0.8	0.8	55
	125	2	16.5		0.7	0.1	2	5.7	2.4	4	4.0	3.2	6
	126	2	14.2	26.0	0.2	0.1	5	2.4	1.3	5	1.4	1.5	10
	127	2	33.8		0.3	0.2	13	3.9	0.8	7	1.6	1.6	21
	129	2	18.8	22.4	0.3	0.2	9	2.7	1.0	6	1.2	1.3	15
	130	6	75.2	39.6	0.4	0.2	31	2.8	1.6	21	1.4	1.6	52
	130a	2	<10 min										
4MAY86	131	2	90.8	20.1	0.6	0.3	7	3.0	1.7	32	2.4	1.8	39
	132	4	<10 min										
	132a	4	63.9		0.7	0.2	13	4.2	2.6	13	2.5	2.6	26
	133	4	20.1	23.2	0.6	0.2	5	2.9	1.0	6	1.8	1.4	11
	134	2	25.2		0.7	0.2	7	2.6	1.8	8	1.7	1.6	15
	135	2											
	137	2	21.0	20.8	0.6	0.2	5	3.6	1.5	5	2.1	1.8	10
	138	4	25.8		0.7	0.2	6	3.1	2.3	7	2.0	2.1	13
	140	2	31.8	40.9	0.5	0.3	14	2.1	1.6	9	1.6	1.5	23
	142	4	30.7		0.6	0.2	28	1.8	0.6	10	0.8	0.7	38
	143	2	28.4		0.7	0.2	2	4.3	2.3	6	3.6	2.6	8
	148	2	15.6					3.1	1.2	5	3.1	1.2	5
	149	2	<10 min										
5MAY86	150	2	11.2		0.5	0.2	3	1.6	0.5	6	1.2	0.7	9
	150a	2	53.0		0.6	0.1	4	3.9	2.2	13	3.1	2.4	17
	151	2	16.7		0.7	0.2	3	2.9	1.3	5	2.1	1.5	8
	152	2	28.4		0.5	0.2	5	2.6	1.1	10	1.9	1.3	15
	153	2	13.9		0.9		1	4.3	0.8	3	3.5	1.6	4
	154	4	22.5		0.9	0.1	2	4.2	1.6	5	3.2	1.8	7
	155	4	59.0		0.6	0.2	10	3.5	2.2	14	1.8	2.0	24
	159	2	30.4		0.6		1	4.3	2.6	7	3.8	2.6	8
6MAY86	160	2	111.8		0.7	0.2	16	3.4	2.5	30	2.4	2.4	46
	161	2	<10 min										
	162	2	68.3		0.4	0.2	16	3.0	1.8	21	1.8	1.9	37
North Migration (Phase B) 1988													
18APR88	401	2	26.4	58.3	0.4	0.3	8	2.6	1.8	9	1.6	1.7	17
	402	2	35.5	15.4	0.4	0.3	5	3.4	1.2	10	2.4	1.7	15
25APR88	405	2	50.1	9.9	0.4	0.3	16	2.1	0.9	21	1.4	1.1	37
27APR88	407	2	71.0	16.1	0.6	0.2	21	3.3	1.9	17	1.9	2.0	38

Appendix E-10. Vessel and aircraft sightings in the study area, April 1986-April 1988.

				Vessels					Aircraft			
Date	Site No.	Hours	Sight-ings	Com. Fish.	Merch.	Oil Supply	Recr.	Unid.	Priv.	Mil.	Com.	Copter
				April-May 1986								
30 Apr	1	0907-1740	0	0	0	0	0	0	0	0	0	0
	2	0909-1722	13	1	0	0	0	3	0	1	0	0
1 May	1	0713-1514	4	0	0	0	0	2	1	0	0	1
	2	1126-1620	15	1	0	0	0	3	1	0	0	0
2 May	1	0908-1725	10	4	-	-	-	2	-	-	-	-
	2	0933-1649	9	1	0	0	0	7	0	0	0	0
4 May	1	0729-1519	15	7	3	0	2	3	0	0	0	0
	2	0748-1429	18	8	2	0	0	7	0	0	0	0
5 May	1	0721-1443	19	18	0	0	0	1	0	0	0	0
	2	0751-1430	6	2	4	0	0	0	0	0	0	0
6 May	1	0730-1011	0	0	0	0	0	0	0	0	0	0
	2	0742-1101	23	9	11	3	0	0	0	0	0	0
Totals				51	20	3	2	28	2	1	0	1
% of Total				49.0	19.2	2.9	1.9	26.9	50.0	25.0	0	25.0
				January 1987								
12 Jan	4	1159-1343	11	3	0	0	0	0	0	0	0	0
17 Jan	4	0903-1310	2	0	0	0	1	0	0	0	0	0
18 Jan	4	0849-1426	19	2	3	0	0	2	0	0	0	0
19 Jan	4	0900-1310	3	1	0	0	0	0	0	0	0	0
20 Jan	4	0811-1631	25	4	0	0	1	0	0	0	0	0
21 Jan	4	0835-1454	11	2	0	0	1	0	0	1	0	1
Totals				12	3	0	3	2	0	1	0	1
% of Total				60.0	15.0	0.0	15.0	10.0	0.0	50.0	0.0	50.0
				March 1987								
17 Mar	3	0827-1219	6	2	1	0	0	0	0	0	0	0
	5	0823-1018	4	1	1	0	0	0	0	0	0	0
25 Mar	3	0813-1235	2	1	0	0	0	0	0	0	0	0
	5	0840-0912	8	1	0	0	0	0	0	0	0	0
26 Mar	3	0709-1336	16	3	0	0	0	0	0	0	0	1
27 Mar	3	0709-1336	29	3	0	0	3	0	0	0	0	3
28 Mar	3	0705-1402	16	2	0	0	5	0	0	0	0	0
29 Mar	3	1109-1225	3	1	0	0	1	0	0	0	0	0
Totals				14	2	0	9	0	0	0	0	4
% of Total				56.0	8.0	0.0	36.0	0.0	0.0	0.0	0.0	100.0
				March-April 1988								
3 Mar	3	0907-1131	1	0	0	1	0	0	0	0	0	0
7 Mar	4	0848-1252	1	0	0	0	0	0	0	0	0	0
8 Mar	4	0730-1702	16	2	0	0	1	0	0	1	1	0
9 Mar	4	0709-1026	0	0	0	0	0	0	0	0	0	0
10 Mar	4	0723-1021	10	2	0	0	0	0	0	0	0	0
11 Mar	3	0650-1232	1	0	1	0	0	0	0	0	0	0
12 Mar	3	0739-1637	19	3	0	0	1	0	0	0	0	0
14 Mar	3	0655-1115	8	3	0	0	0	0	0	0	0	0
15 Mar	4	0758-1252	0	0	0	0	0	0	0	0	0	0
16 Mar	4	0648-1344	1	1	0	0	0	0	0	0	0	0
17 Mar	4	0714-1612	6	0	0	0	2	0	0	0	0	0
18 Mar	4	0625-1050	13	5	0	0	1	0	0	0	0	0
18 Apr	3	0849-1522	2	1	0	0	0	0	0	0	0	0
25 Apr	3	0726-1134	3	0	0	0	1	0	0	0	0	0
27 Apr	3	0635-1600	1	1	0	0	0	0	0	0	0	0
28 Apr	6	0753-0944	3	0	0	0	0	0	0	1	0	0
Totals				18	1	1	6	0	0	2	1	0
% of Total				69.2	3.8	3.8	23.1	0	0	66.7	33.3	0

Appendix E-11. Results of transect analysis with 95% confidence intervals.

South Migration 1987, Transect Distance Offshore

Transects	Mean	Std dev	Count	Std err	95% Conf. Intervals	
					(+)	(-)
2	8.61	-	1	-	-	-
3	7.74	-	1	-	-	-
5	4.39	-	1	-	-	-
6	5.62	3.28	6	1.34	9.07	2.17
7	3.42	1.60	9	0.53	4.65	2.19
8	4.08	1.82	17	0.44	5.01	3.15
9	4.14	2.16	27	0.42	5.00	3.29
10	3.31	2.54	35	0.43	4.15	2.47
11	0.74	0.14	5	0.06	0.91	0.58
13	8.07	2.33	14	0.62	9.41	6.73
14	8.73	1.13	7	0.43	9.77	7.68
15	9.74	1.28	3	0.74	12.91	6.56

Phase A 1987-88, Transect Distance Offshore

Transects	Mean	Std dev	Count	Std err	95% Conf. Intervals	
					(+)	(-)
1	7.71	2.58	2	1.82	30.90	-15.49
2	4.89	4.25	3	2.45	15.44	-5.66
3	4.94	3.70	3	2.14	14.13	-4.26
4	4.54	2.54	7	0.96	6.89	2.20
5	4.30	2.37	13	0.77	6.06	2.64
6	3.16	1.69	15	0.47	4.16	2.14
7	3.02	1.83	15	0.50	4.15	1.87
8	3.87	1.83	10	0.62	5.45	2.59
9	2.81	1.59	11	0.52	4.08	1.75
10	2.08	1.40	22	0.31	2.75	1.44
11	1.16	1.29	38	0.21	1.57	0.75
12	3.19	0.78	4	0.39	4.43	1.95
13	3.76	1.50	13	0.42	4.67	2.86
14	4.91	1.60	3	0.92	8.88	0.94
15	8.59	-	1	-	-	-

Phase B 1986, 1988, Transect Distance Offshore

Transects	Mean	Std dev	Count	Std err	95% Conf. Intervals	
					(+)	(-)
3	0.35	-	1	-	-	-
4	0.29	0.04	2	0.02	0.60	-0.03
5	0.28	0.10	2	0.07	1.17	-0.61
6	0.31	0.17	3	0.10	0.72	-0.11
7	0.36	0.08	2	0.06	1.12	-0.40
8	0.95	0.92	2	0.65	9.21	-7.31
9	1.41	0.52	2	0.37	6.04	-3.23
10	0.35	0.11	12	0.03	0.42	0.28
11	0.17	0.13	35	0.02	0.21	0.13
12	0.58	0.29	28	0.05	0.69	0.47
13	0.83	0.57	31	0.10	1.03	0.63
14	0.59	0.24	22	0.05	0.70	0.49
15	0.37	0.11	13	0.03	0.44	0.31

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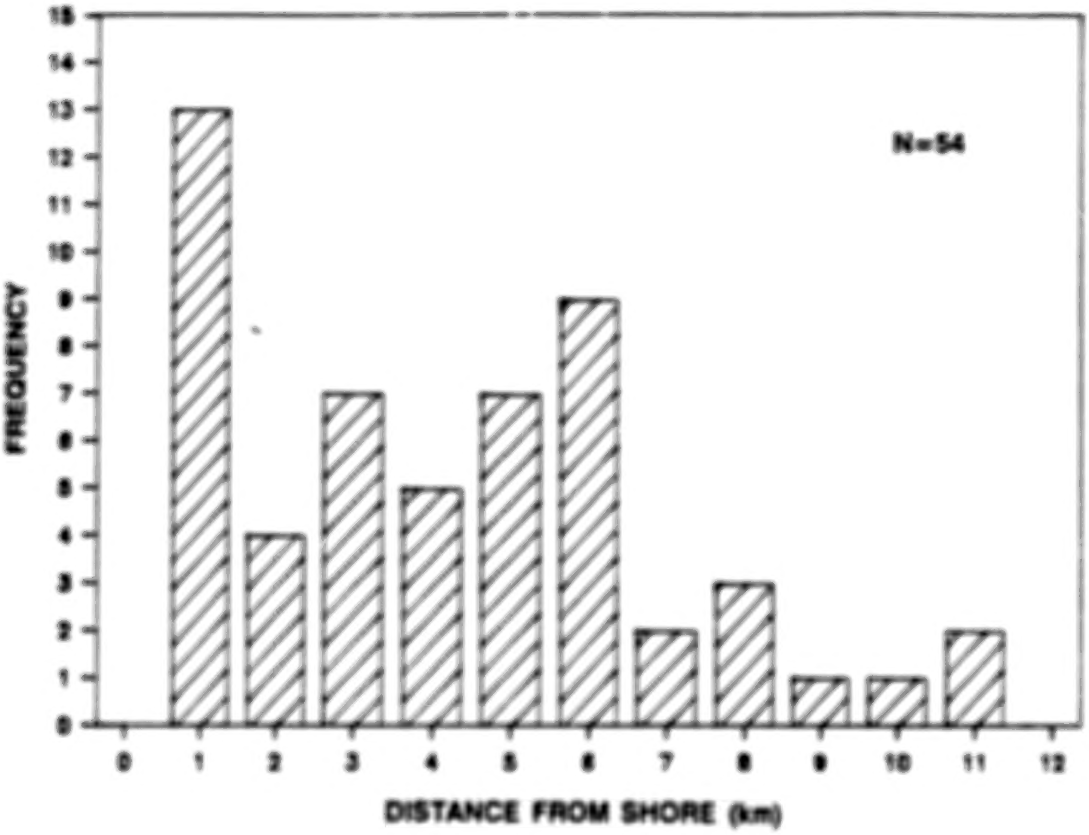
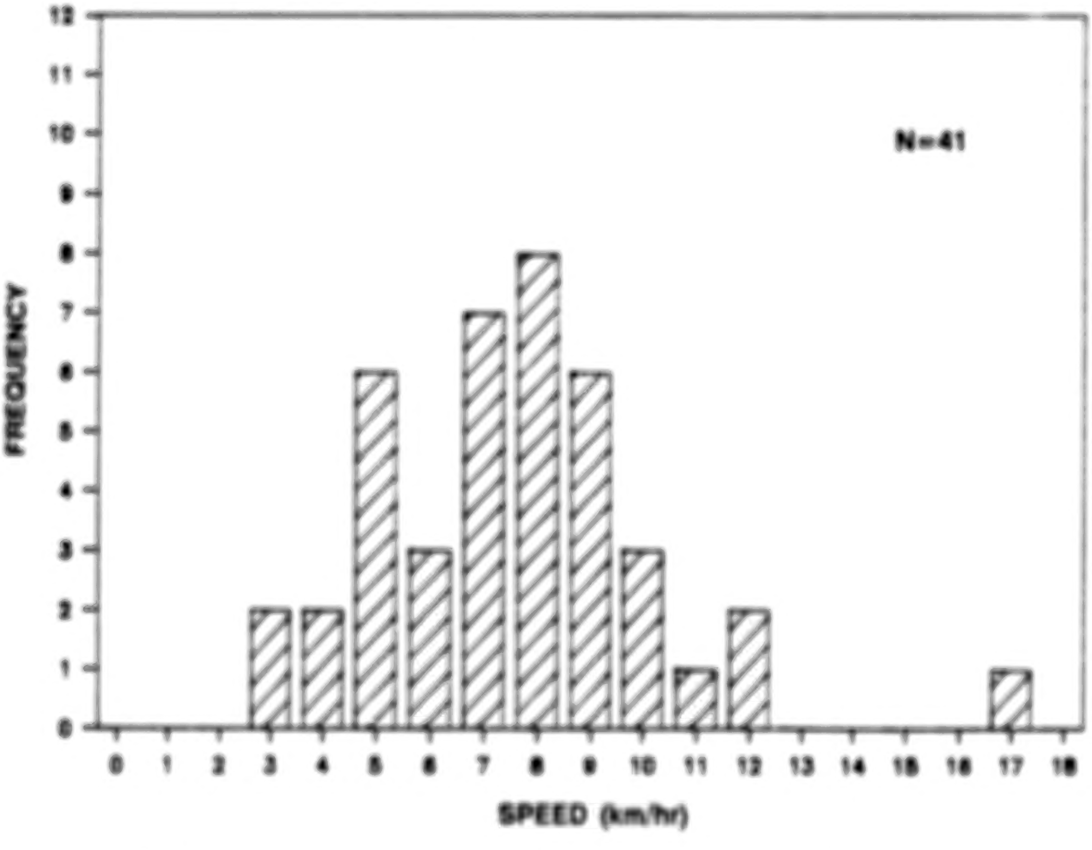
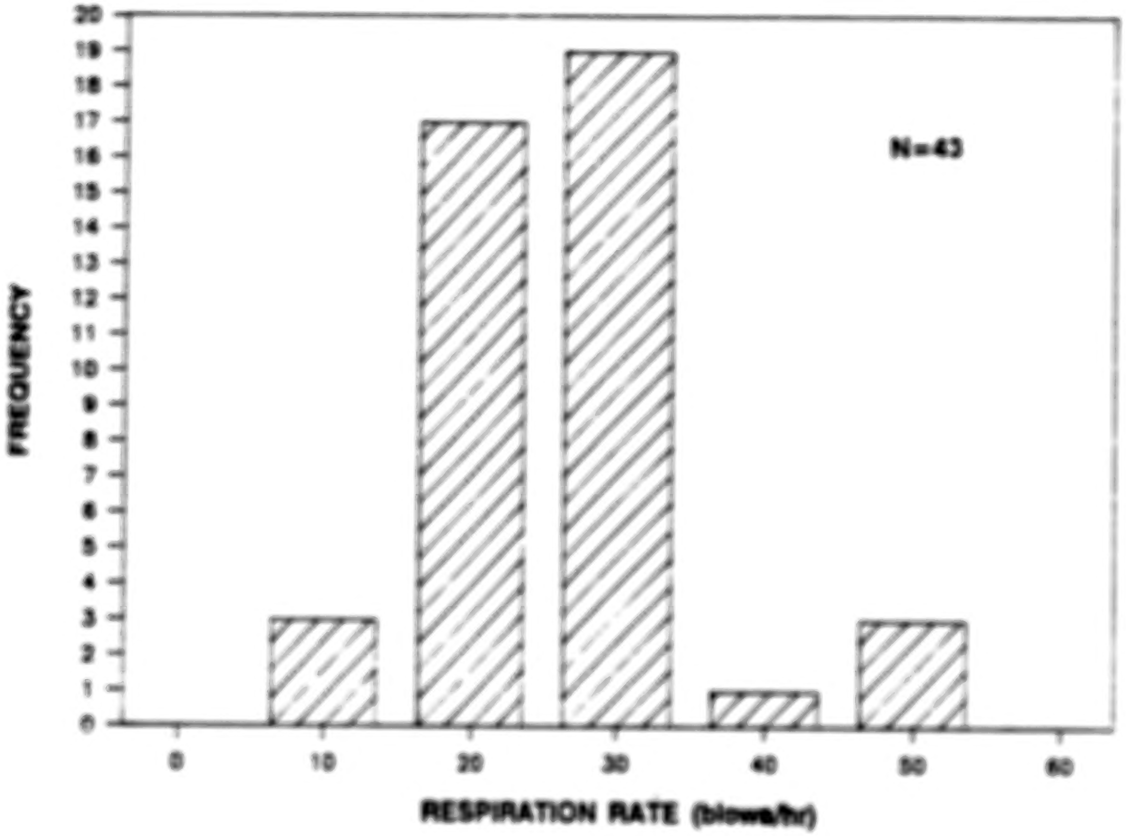


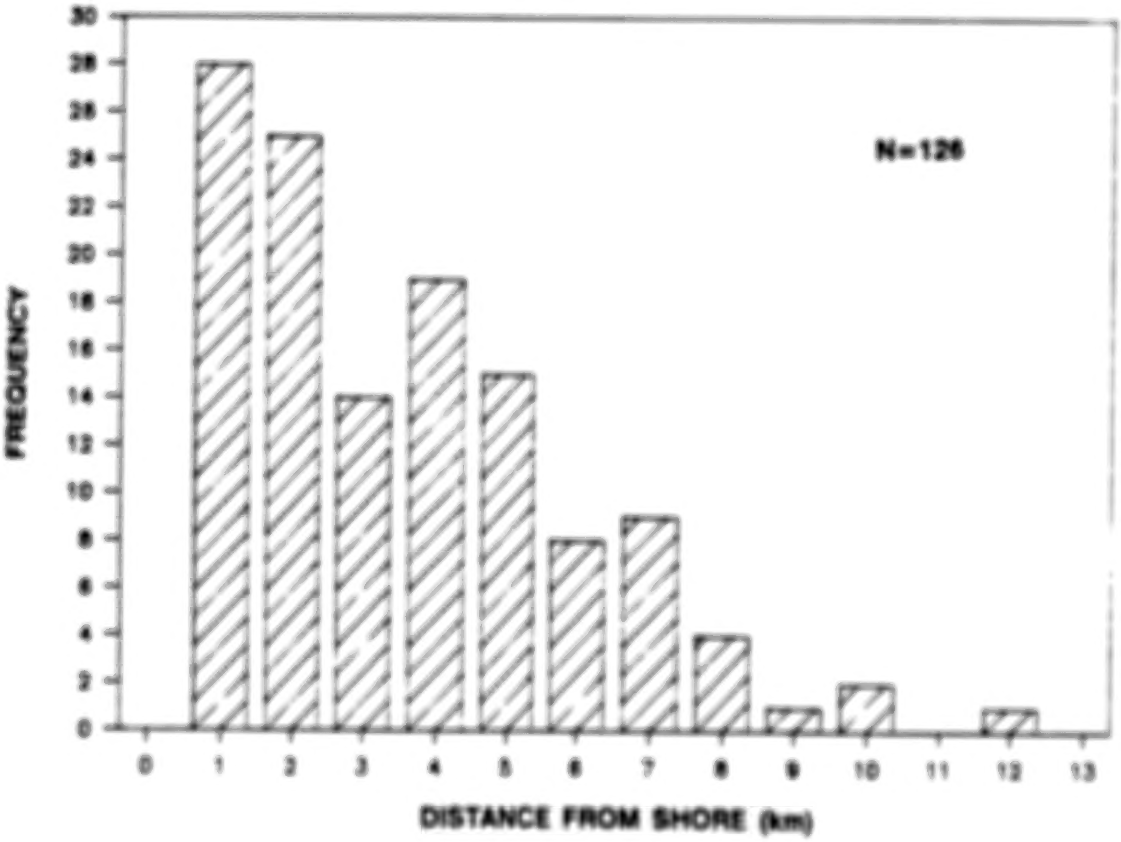
Appendix E-12. Numbers of gray whales as a function of distance from shore, southbound migration.



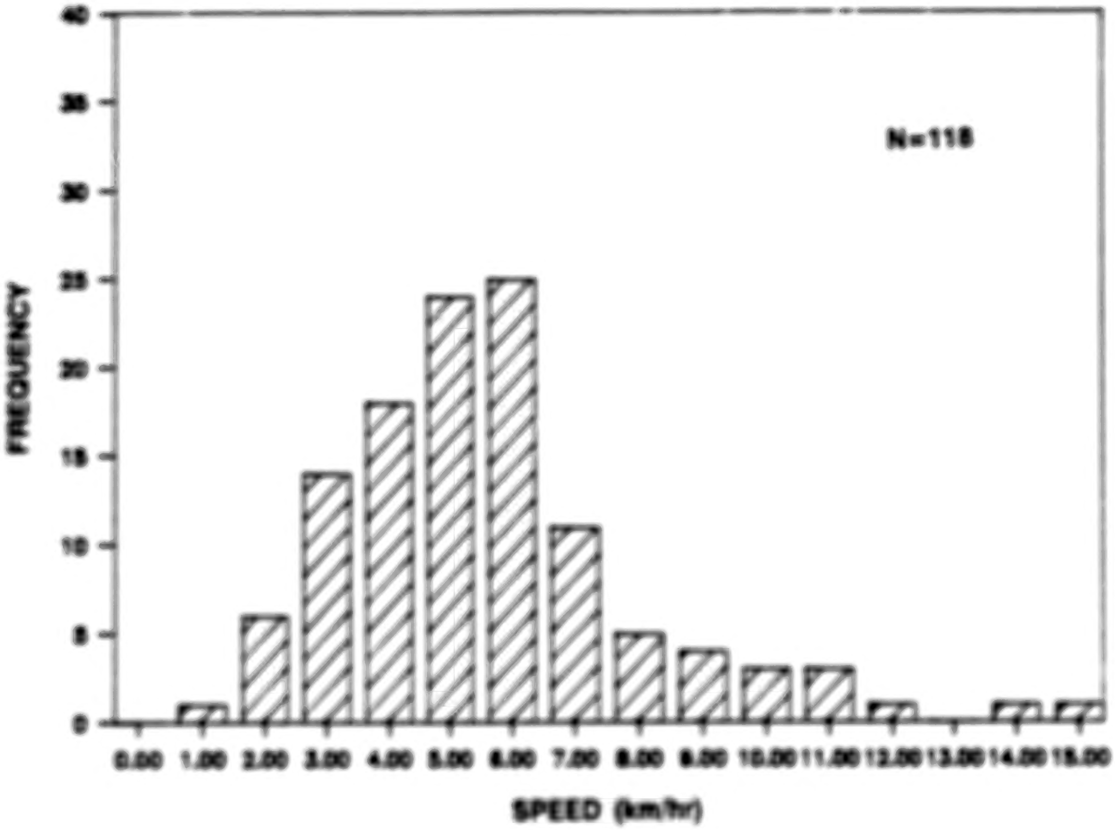
Appendix E-13. Calculated swimming speed of gray whales, southbound migration.



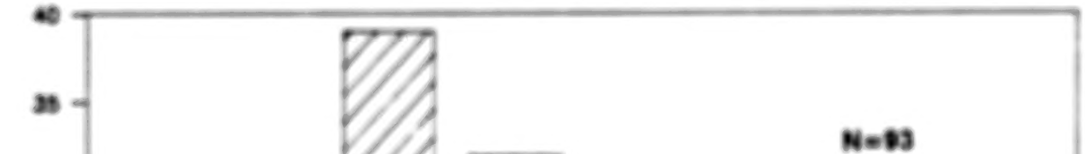
Appendix E-14. Calculated respiration rates of gray whales, southbound migration.



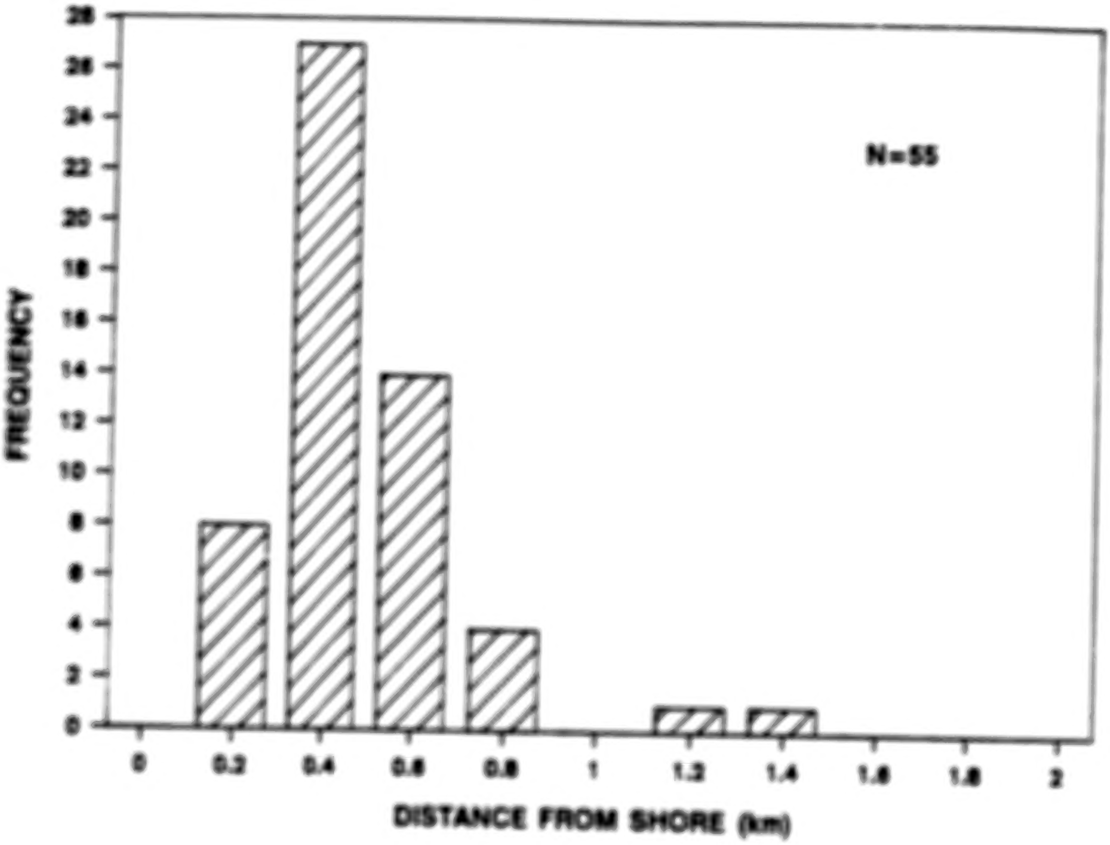
Appendix E-15. Numbers of gray whales as a function of distance from shore, northbound, Phase A migration.



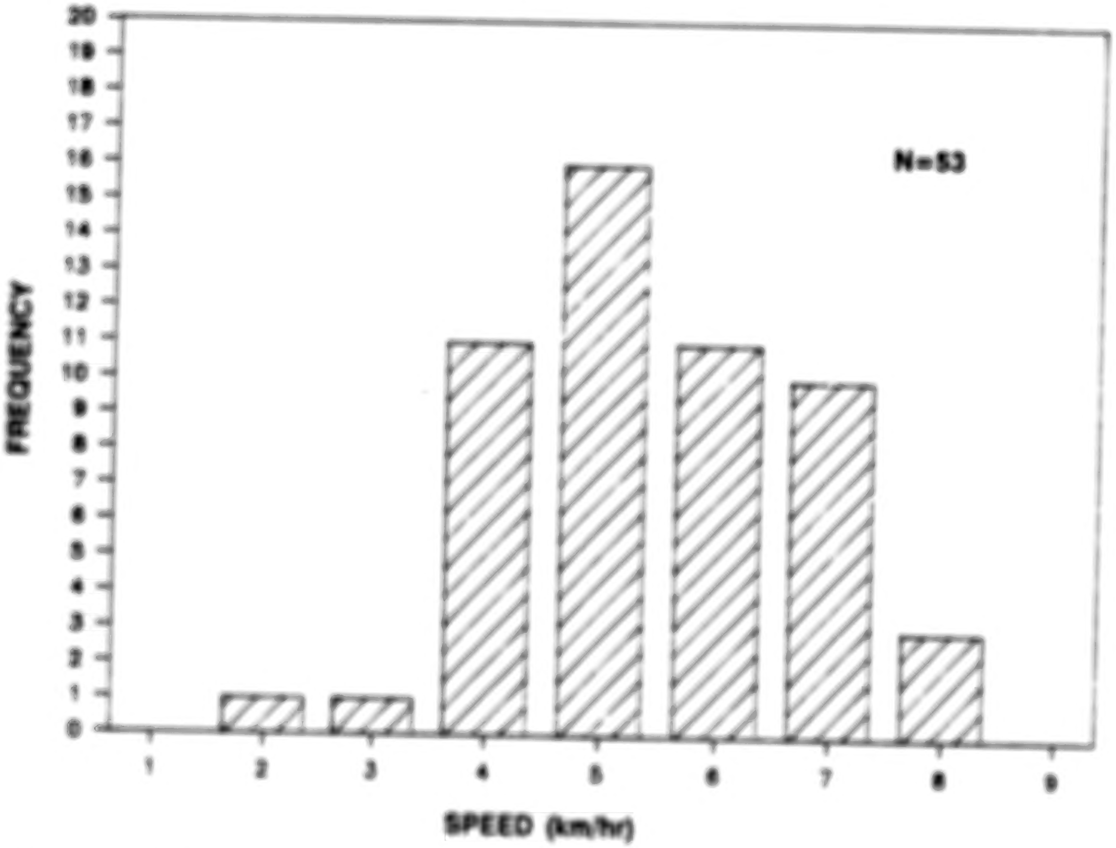
Appendix E-16. Calculated swimming speed of gray whales, northbound, Phase A migration.



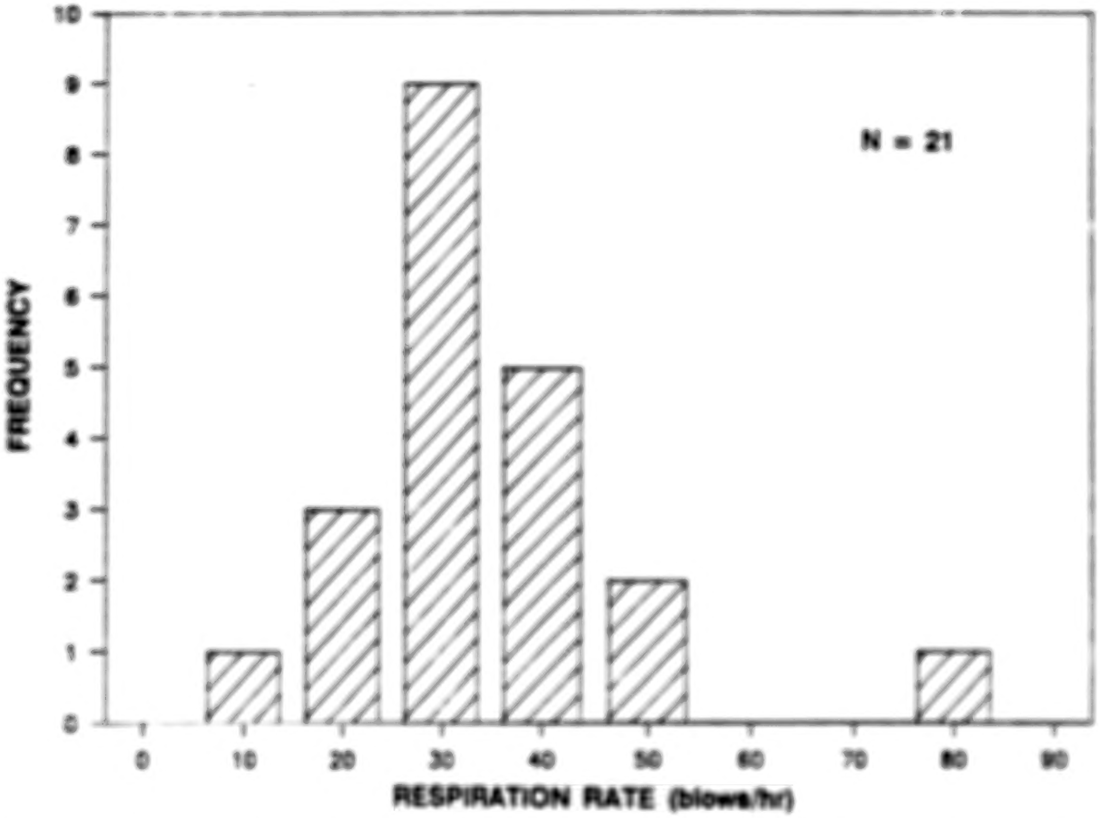
Appendix E-17. Calculated respiration rates of gray whales, northbound, Phase A migration.



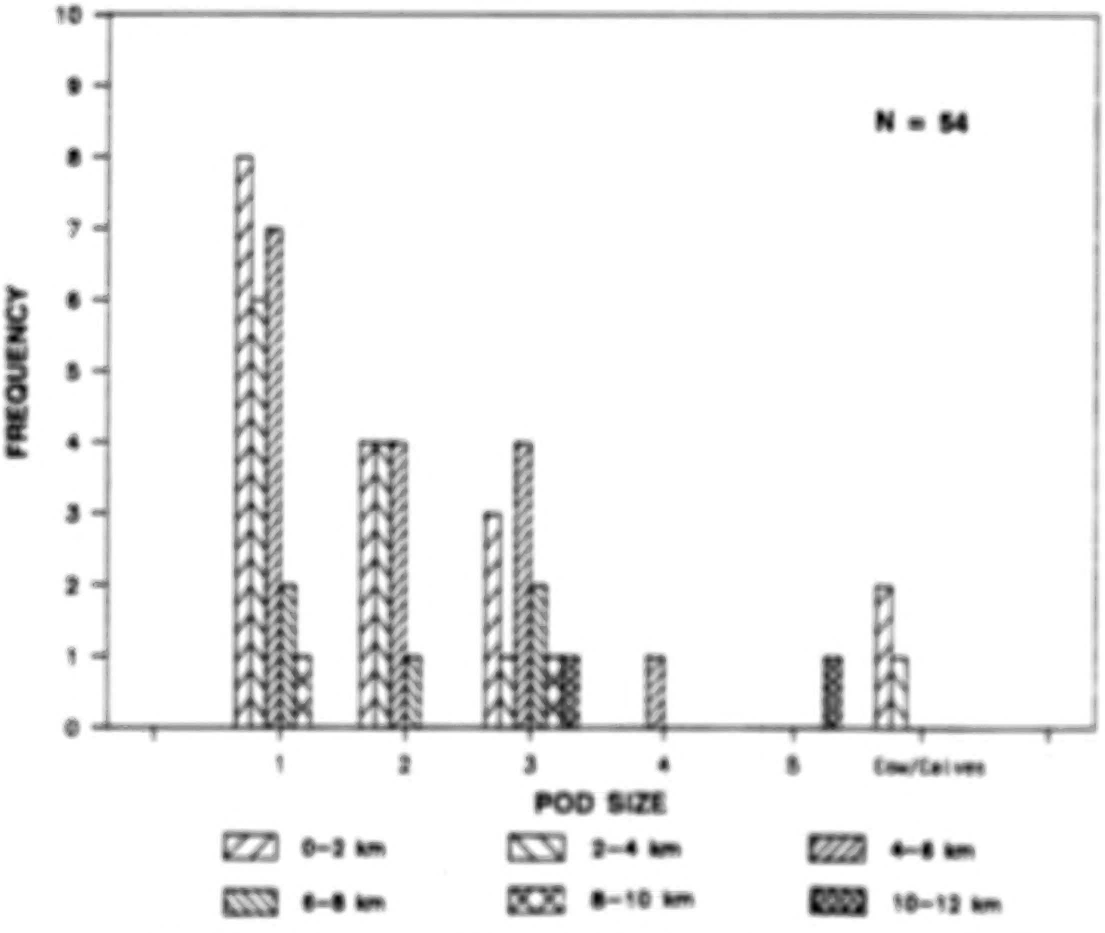
Appendix E-18. Numbers of gray whales as a function of distance from shore, northbound, Phase B migration.



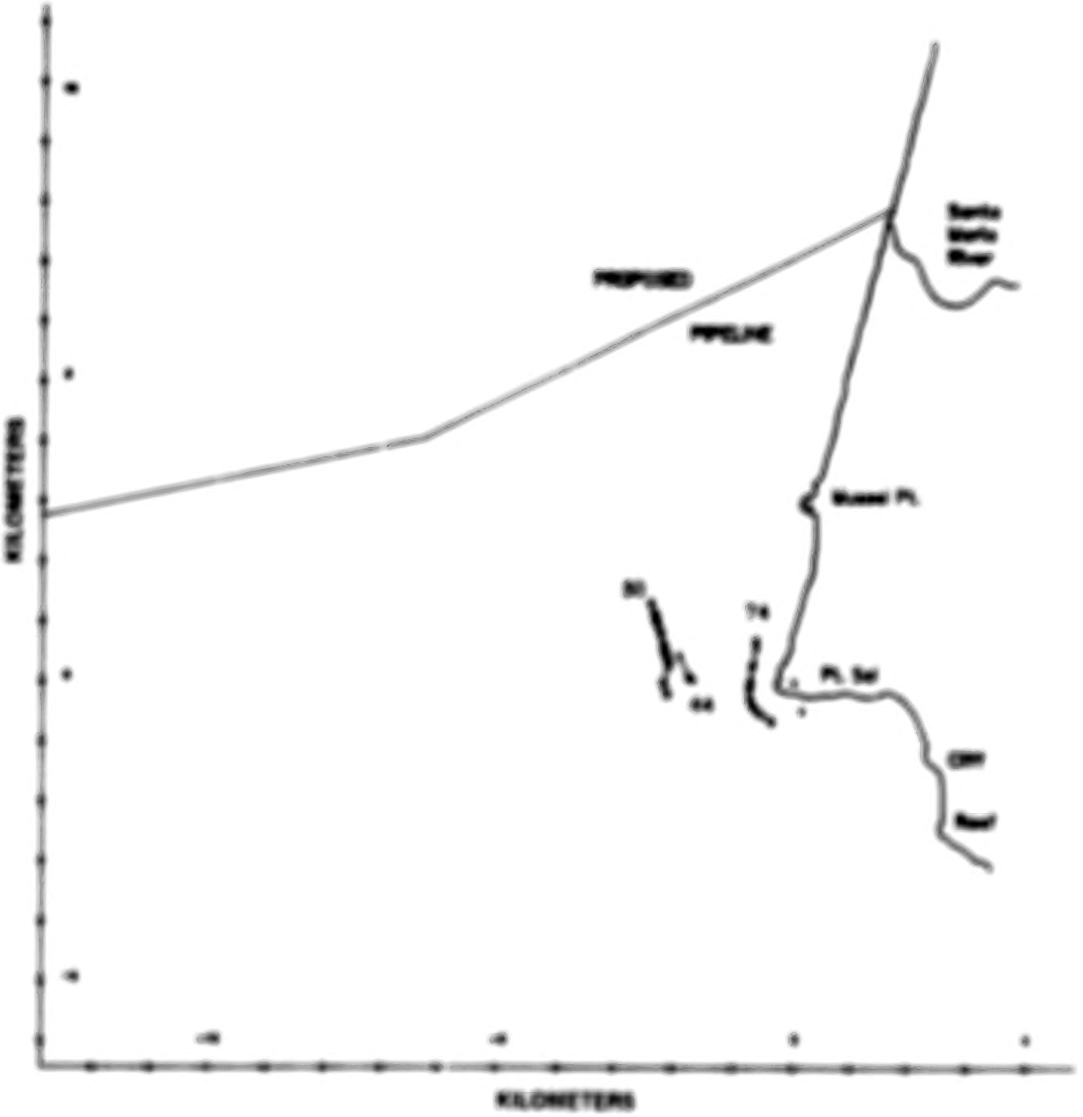
Appendix E-19. Calculated swimming speed of gray whales, northbound, Phase B migration.



Appendix E-20. Calculated respiration rates of gray whales, northbound, Phase B migration.



Appendix E-21. Numbers of gray whales by pod size and distance from shore, southbound migration.



Appendix E-22. Routes taken by three cow-calf pairs, southbound migration.

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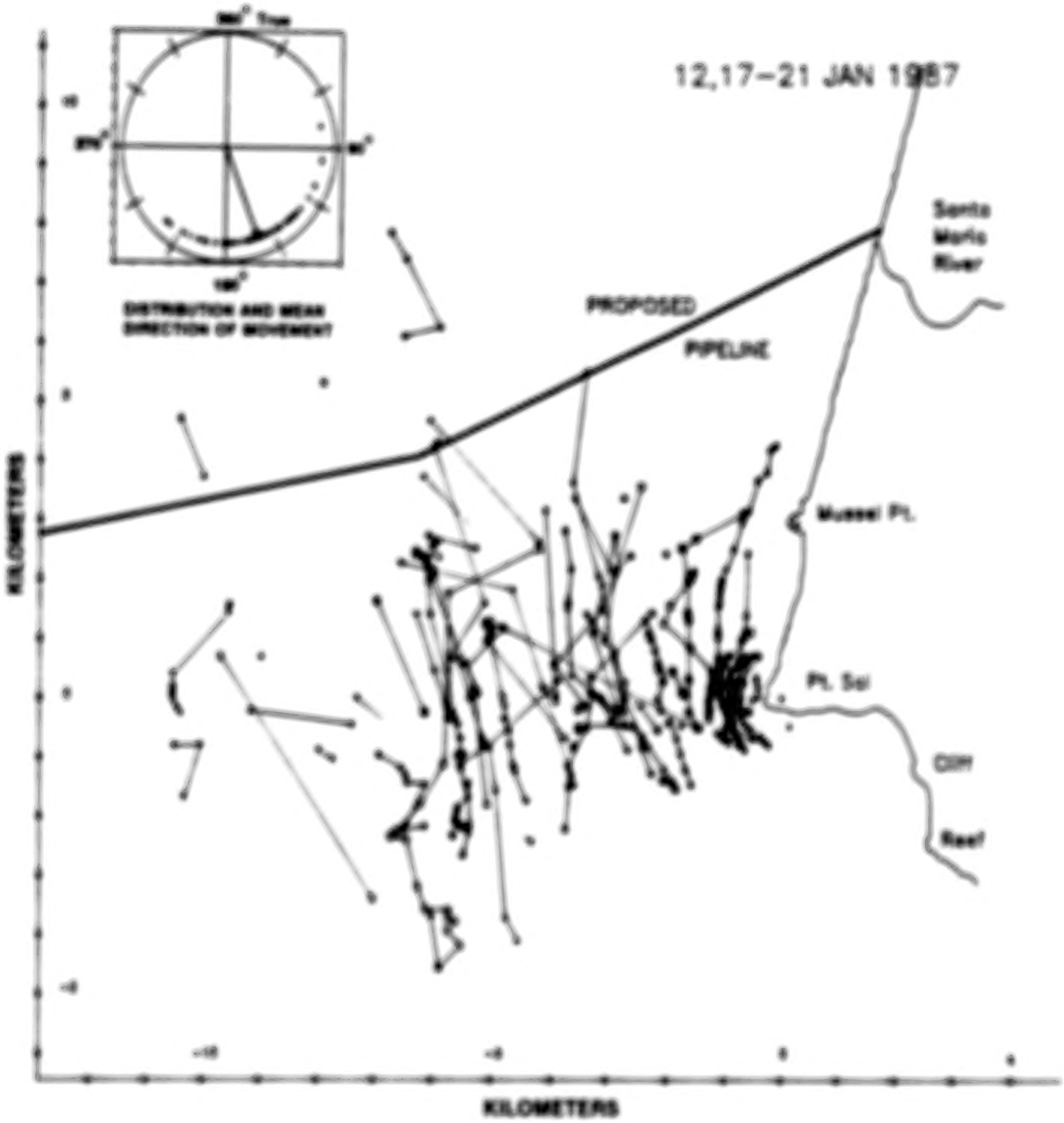

Appendix E-23. Composite routes taken by gray whale pods, southbound migration.

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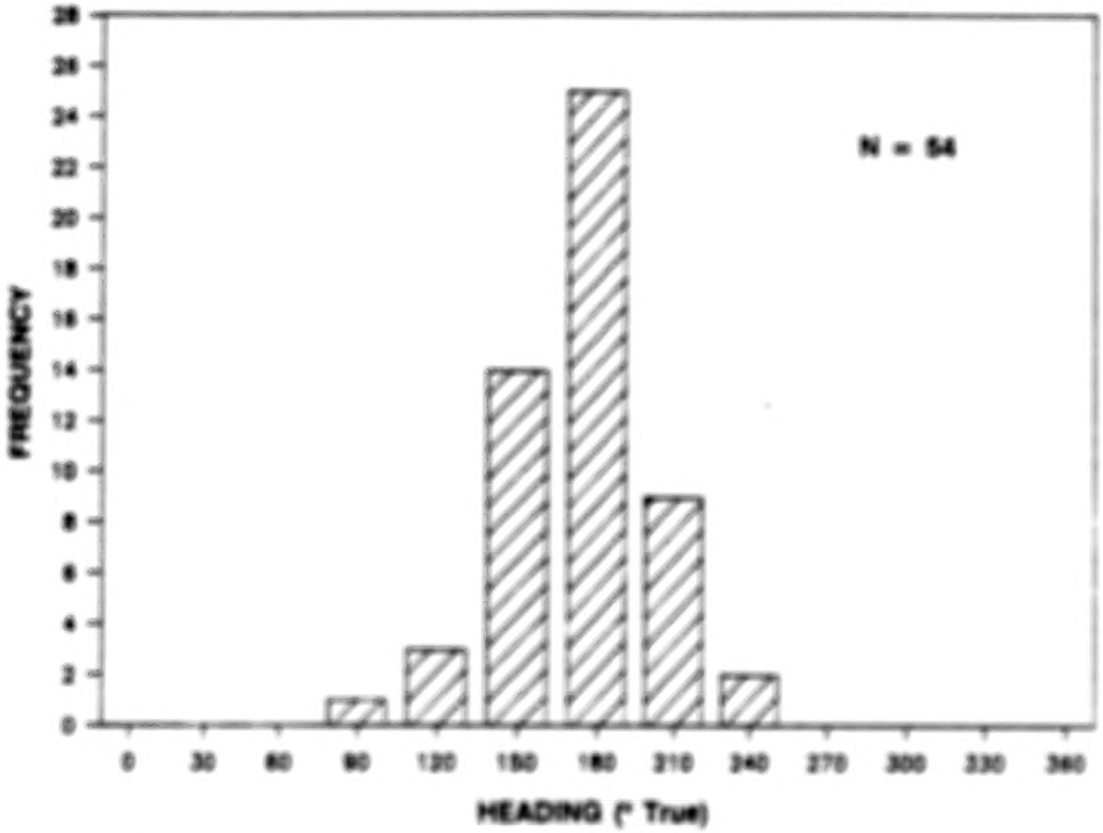
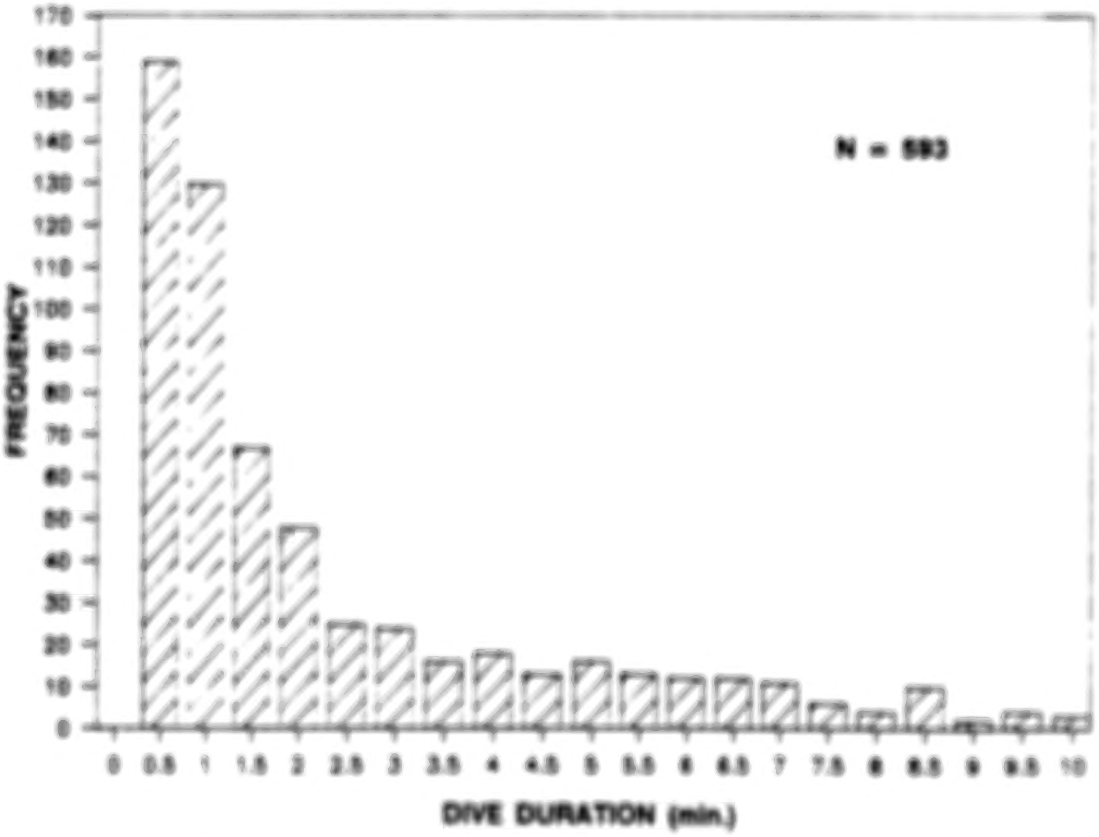
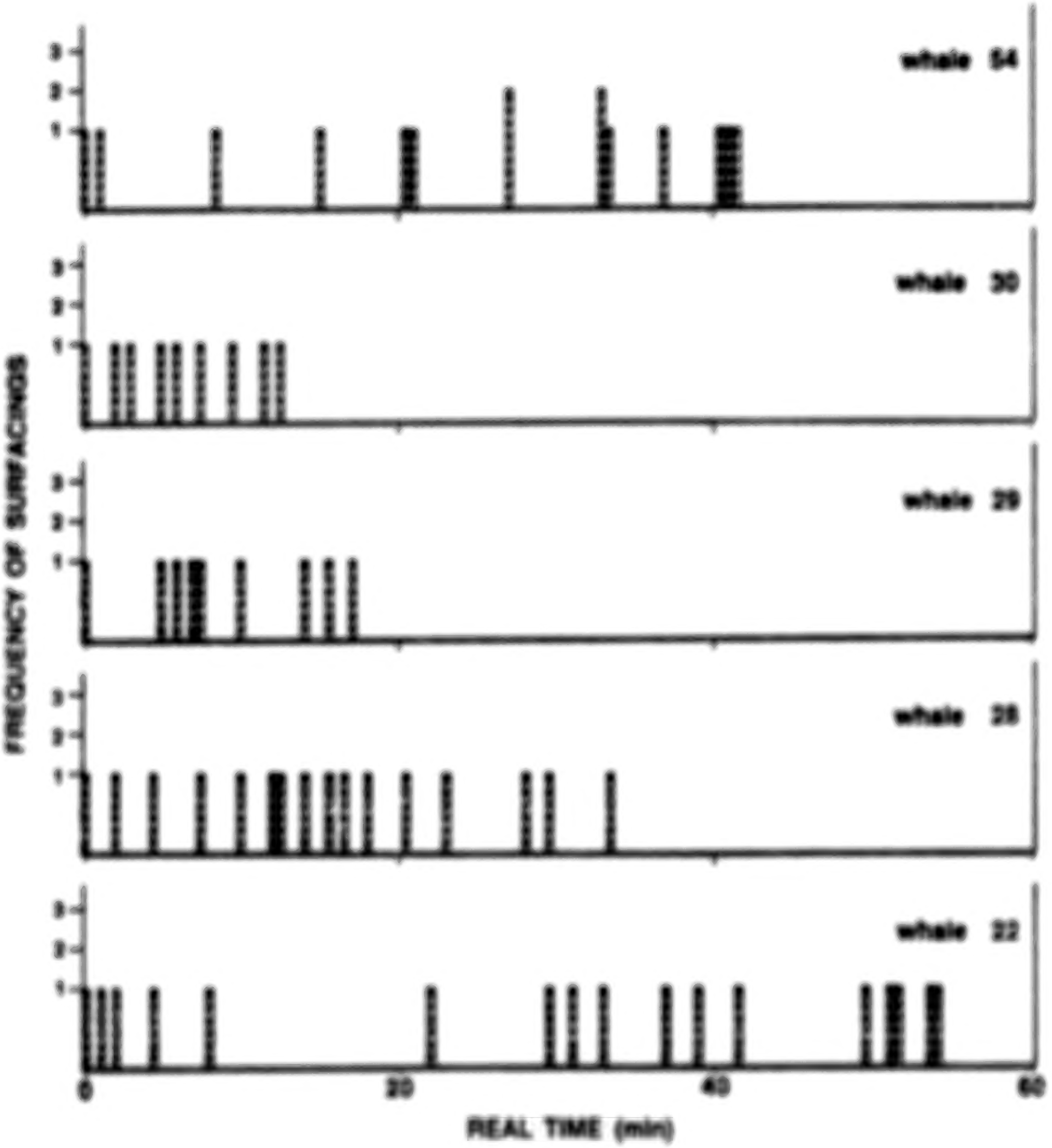


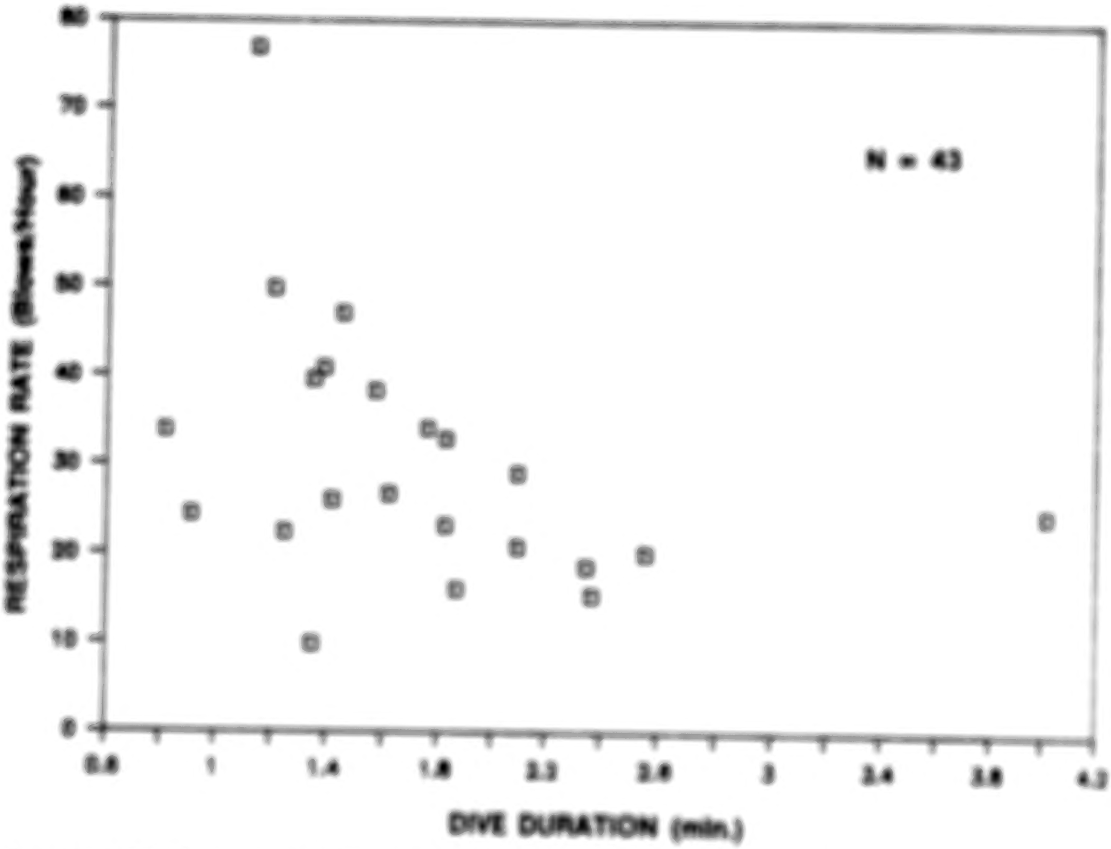
Appendix E-24. Frequency of headings of gray whales, southbound migration.



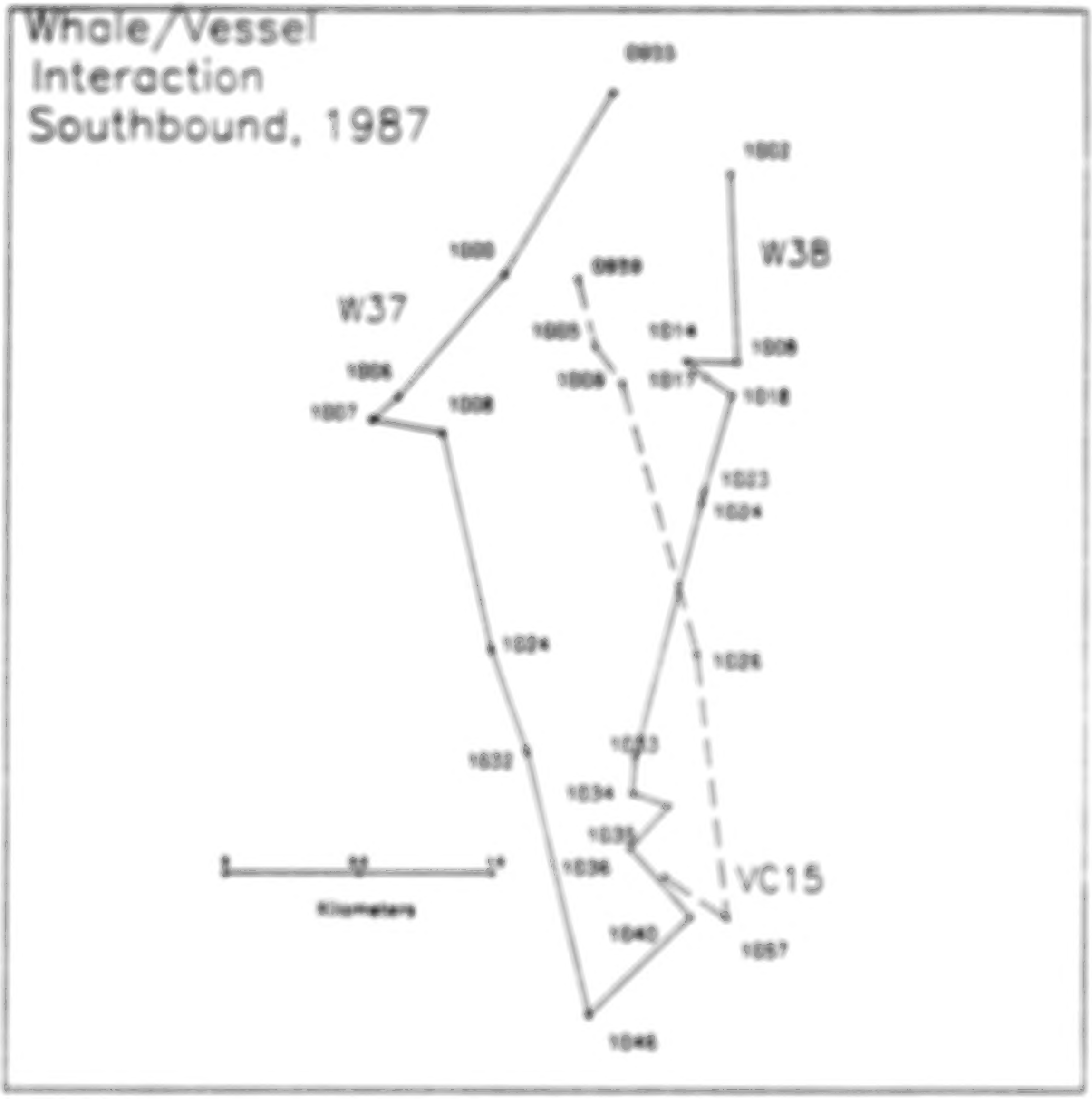
Appendix E-25. Frequency distribution of dive durations of gray whales, southbound migration.



Appendix E-28. Surface-dive sequences of five pods of gray whales, southbound migration.



Appendix E-27. Relationship between dive duration and respiration rate of gray whales, southbound migration.



Appendix E-28. Routes of two pods of gray whales and a fishing vessel during an interaction, 20 January 1987, southbound migration.

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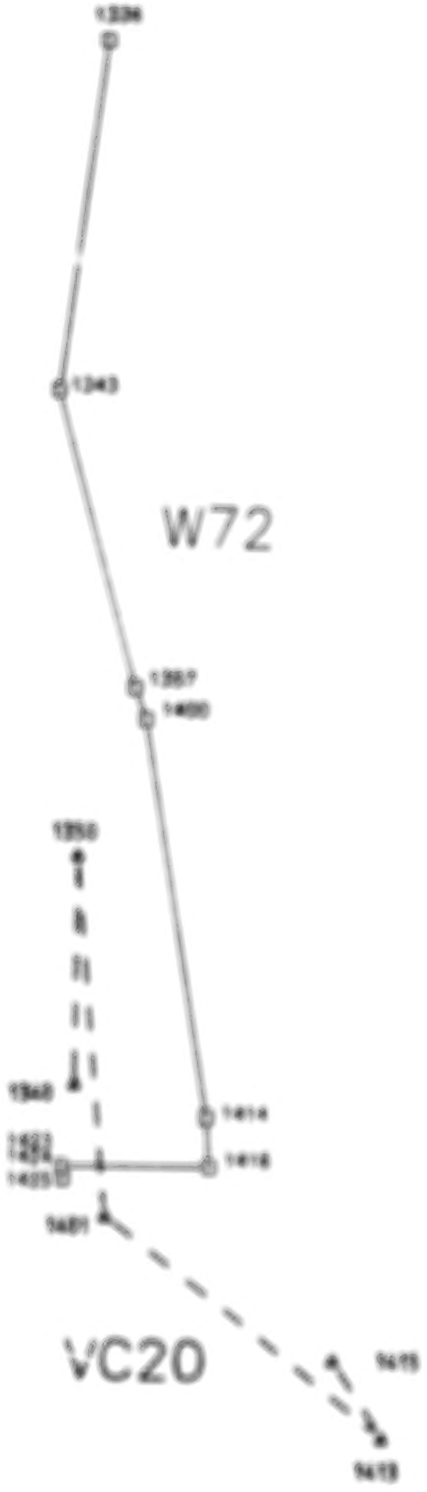
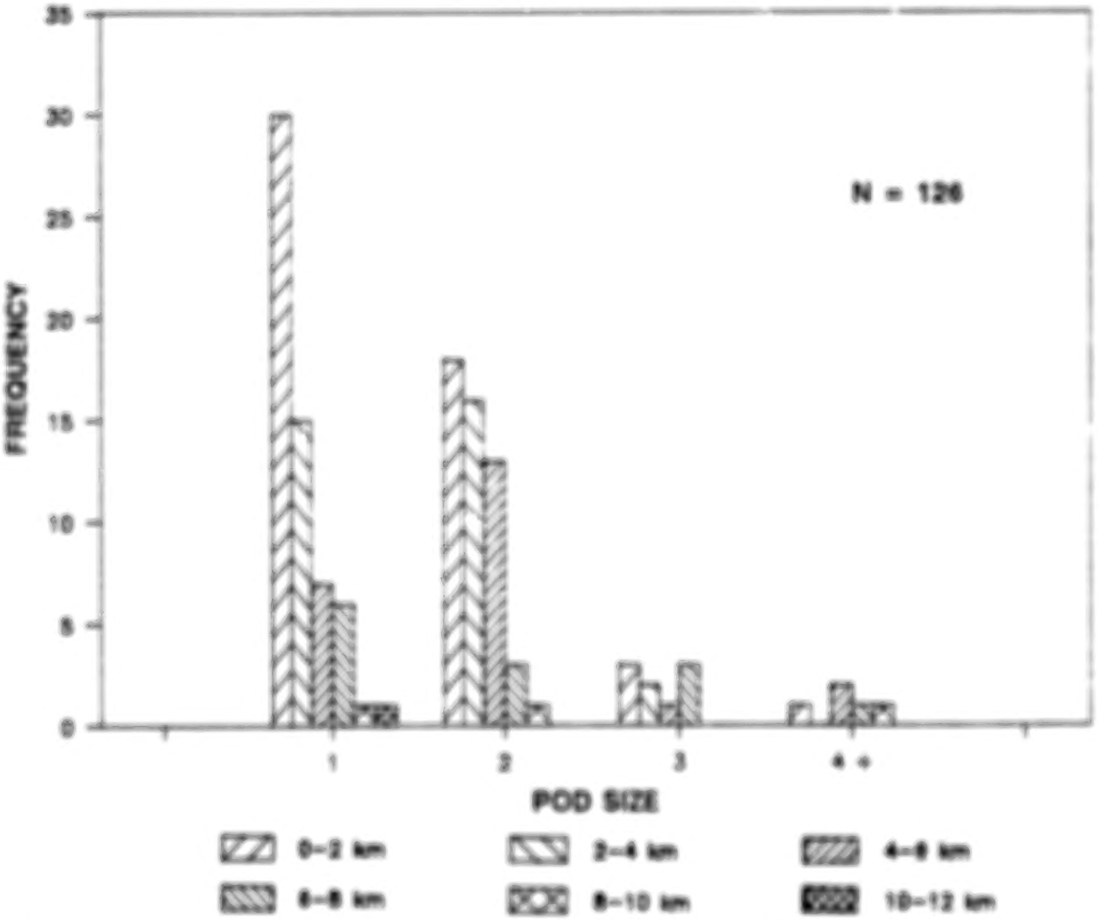


Appendix E-29. Routes taken by a pod of gray whales and a fishing vessel during an interaction, 21 January 1997, southbound migration.

Appendix E-30. A summary of sightings of gray whales by pod size and numbers of individuals, northbound migration.

	Pods			Whales		
Pod Size	n	% By Phase	% By Animals	n	% By Phase	% By Animals
Phase A						
1	96	57.5	44.2	96	36.9	25.9
2	58	34.7	26.7	116	44.6	31.3
3	8	4.8	3.7	24	9.2	6.5
4	4	2.4	1.8	16	6.2	4.3
8	1	0.6	0.5	8	3.1	2.2
Subtotal	167	100.0	77.0	260	100.00	70.1
Phase B						
2	44	88.0	20.3	88	79.3	23.7
3	1	2.0	0.5	3	2.7	0.8
4	5	10.0	2.3	20	18.0	5.4
Subtotal	50	100.0	23.0	111	100.0	29.9
Non-Cow/Calves	-	-	-	315	84.9	84.9
Calves Only	-	-	-	56	15.1	15.1
All Northbound	217	100.0	100.0	371	100.00	100.0



Appendix E-31. Frequency of gray whale sightings by pod size and distance from shore, northbound, Phase A migration.

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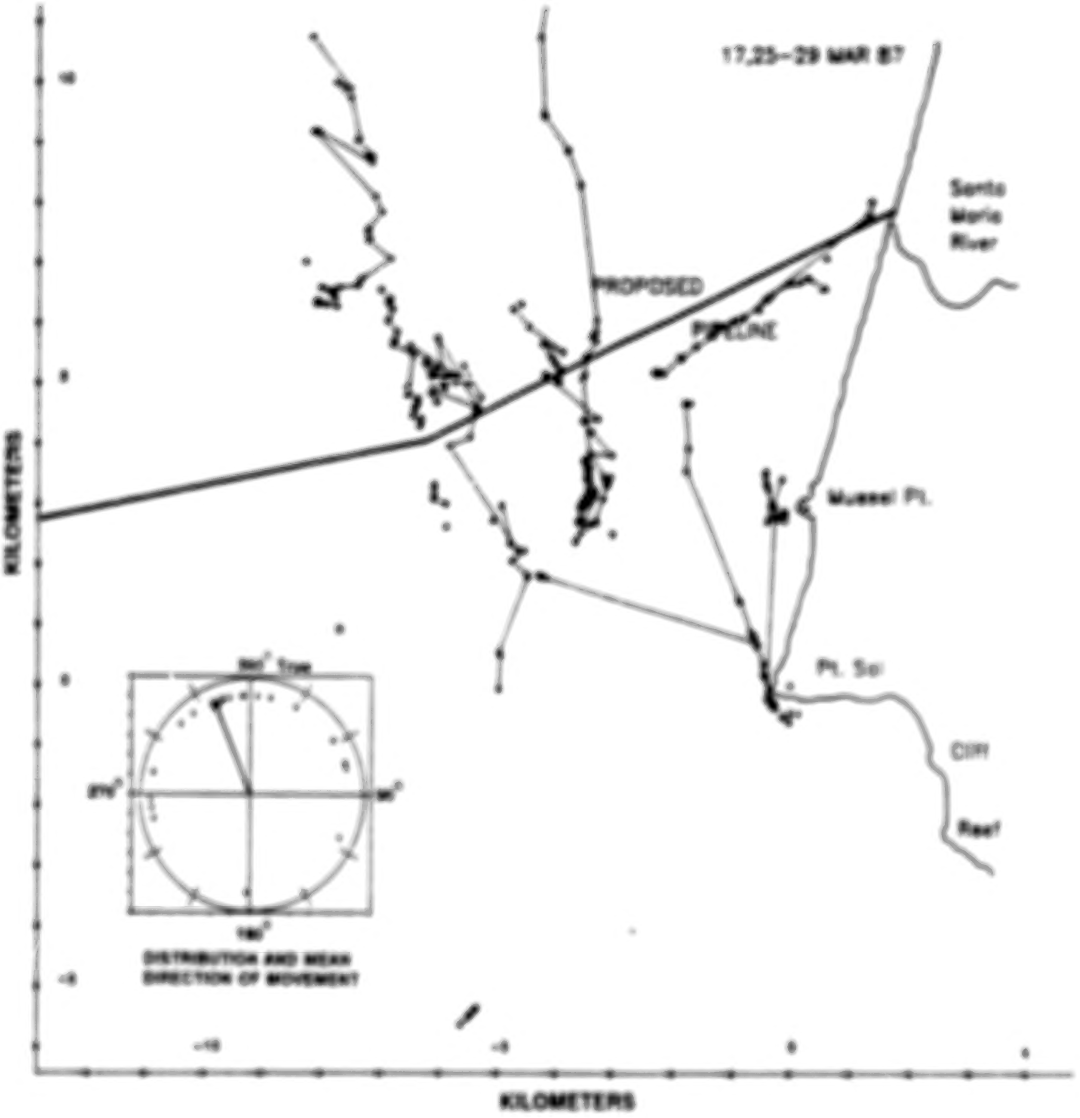
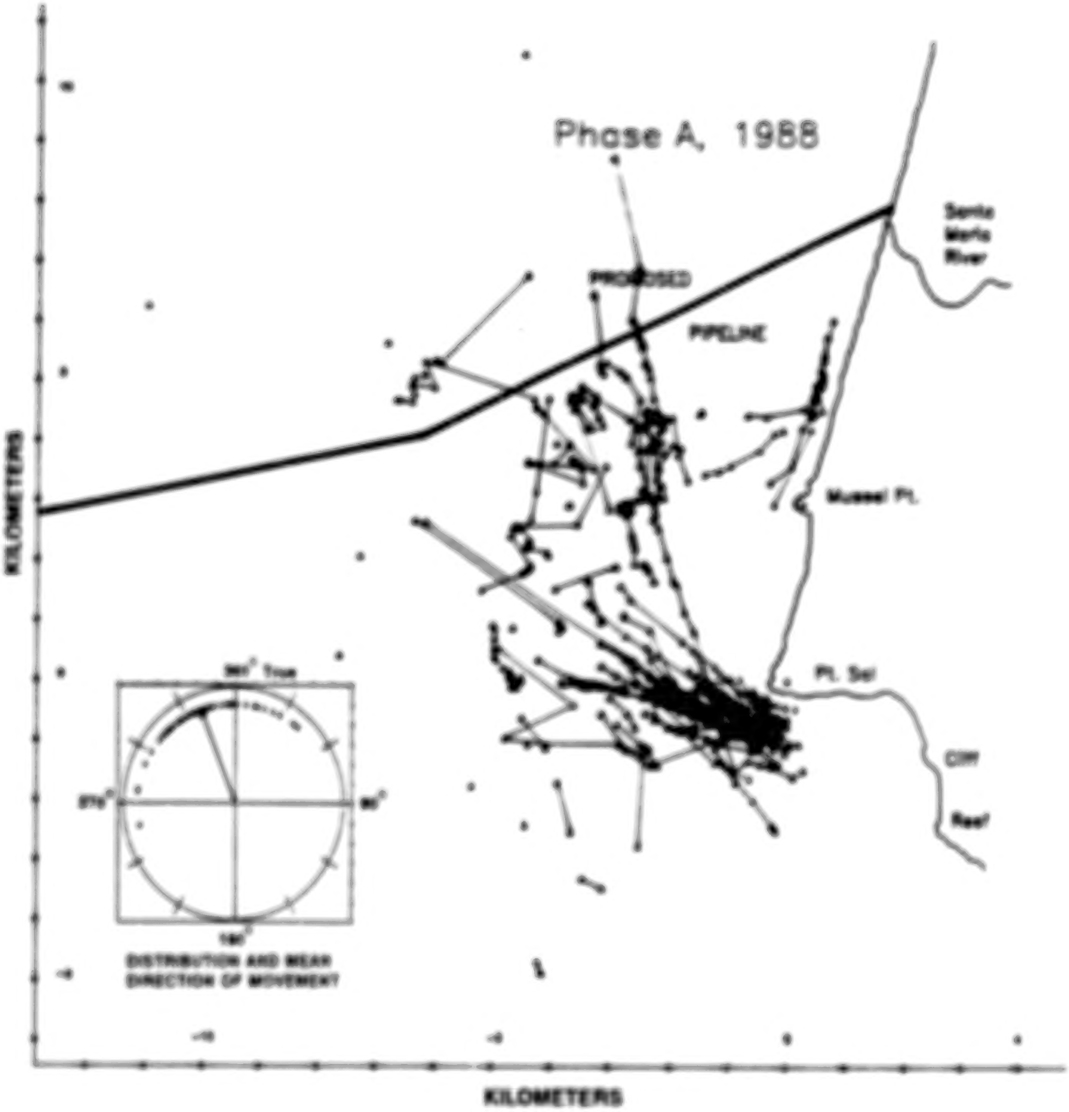
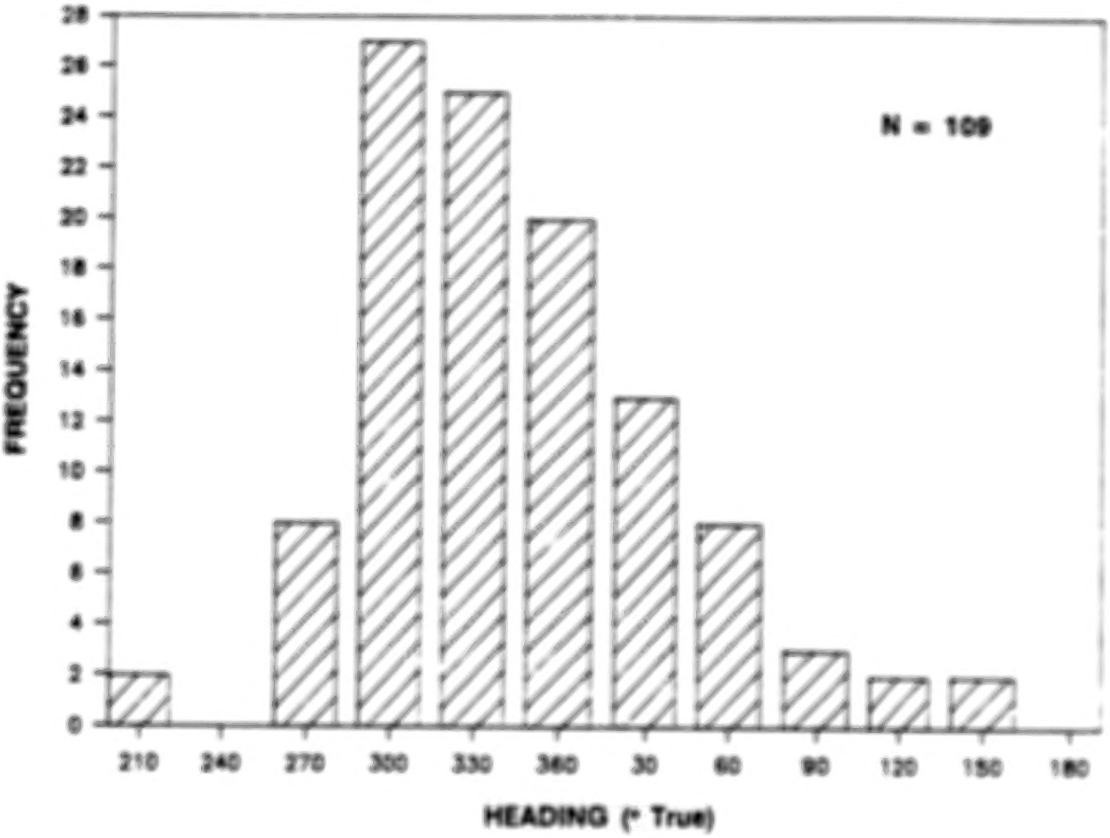


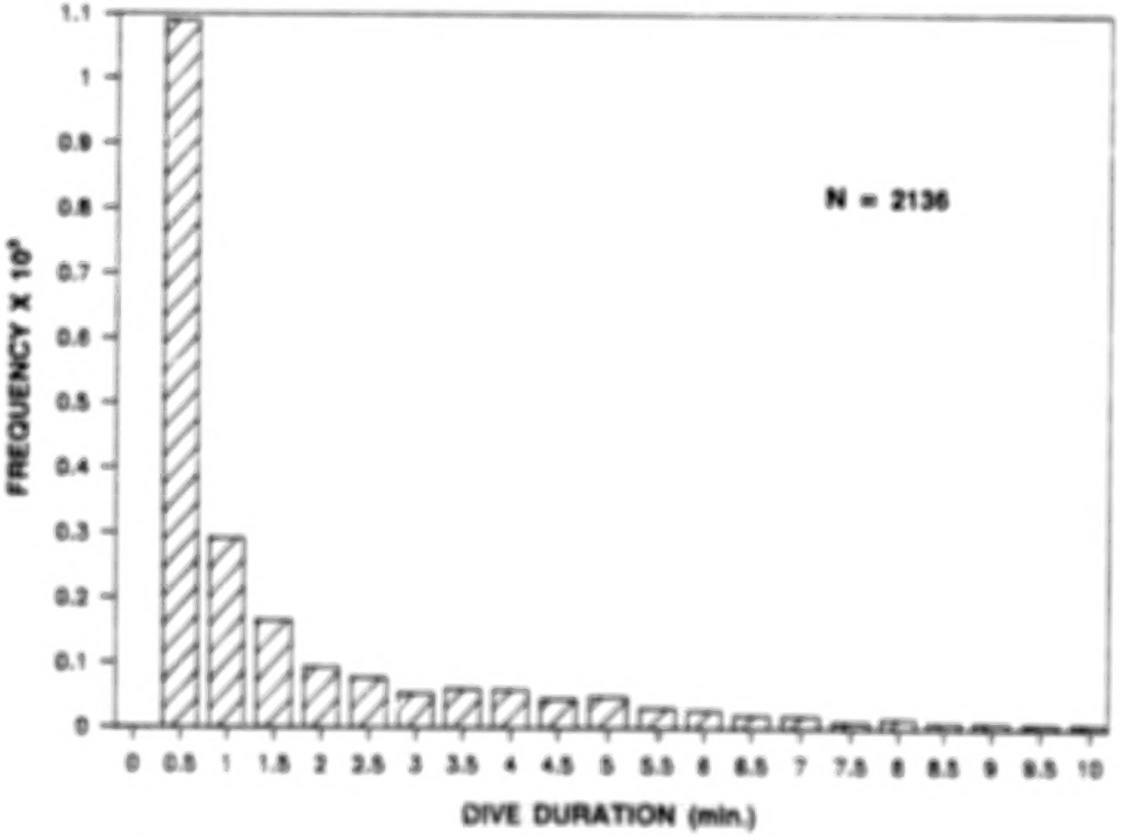
Appendix E-32. Composite routes taken by gray whales, northbound, Phase A migration, 1987.



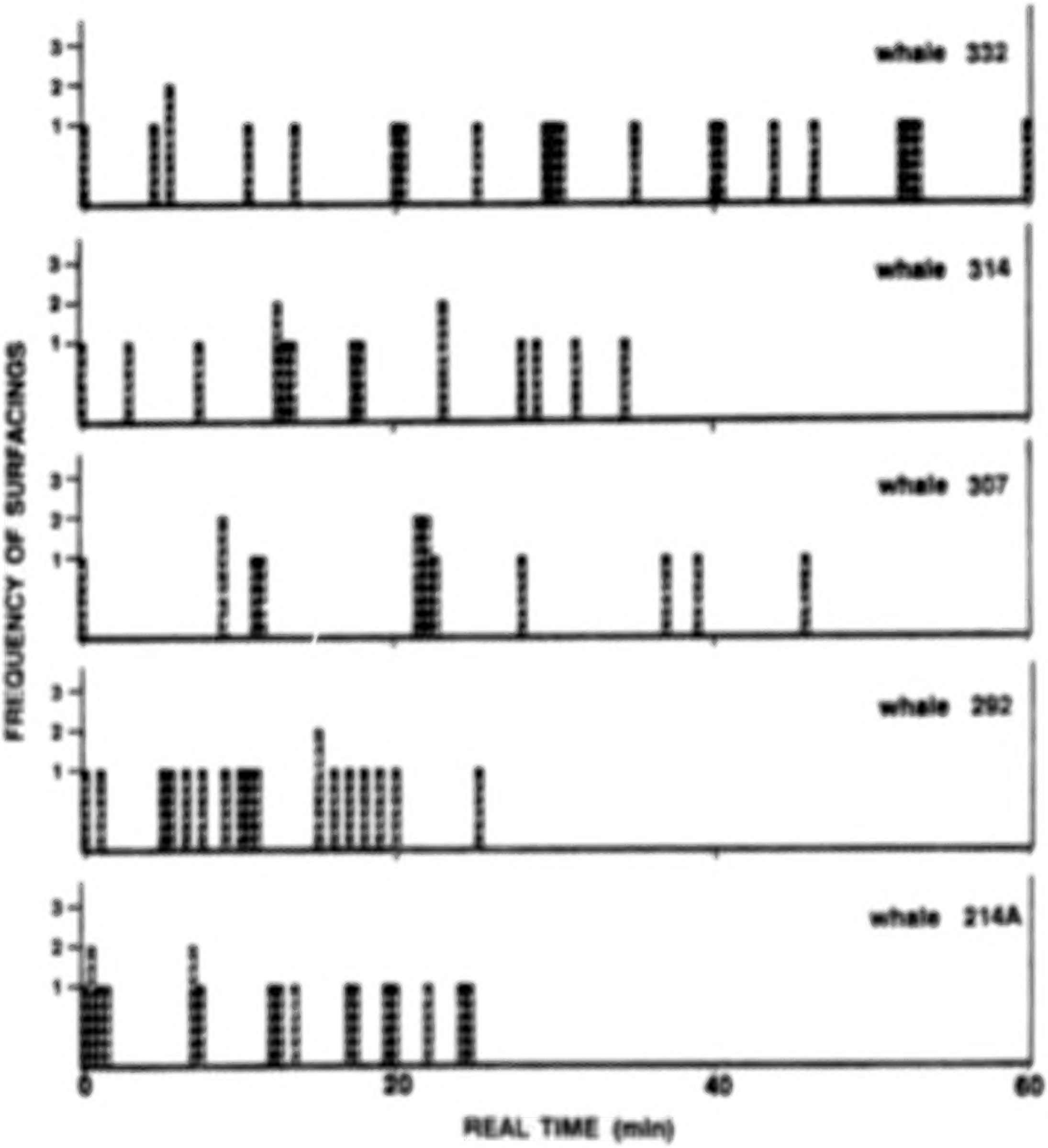
Appendix E-33. Composite routes taken by gray whales, northbound, Phase A migration, 1988.



Appendix E-34. Frequency of headings, northbound, Phase A migration.



Appendix E-35. Frequency distribution of dive durations of gray whales, northbound, Phase A migration.



Appendix E-36. Surface-dive sequences of five pods of gray whales, northbound, Phase A migration.

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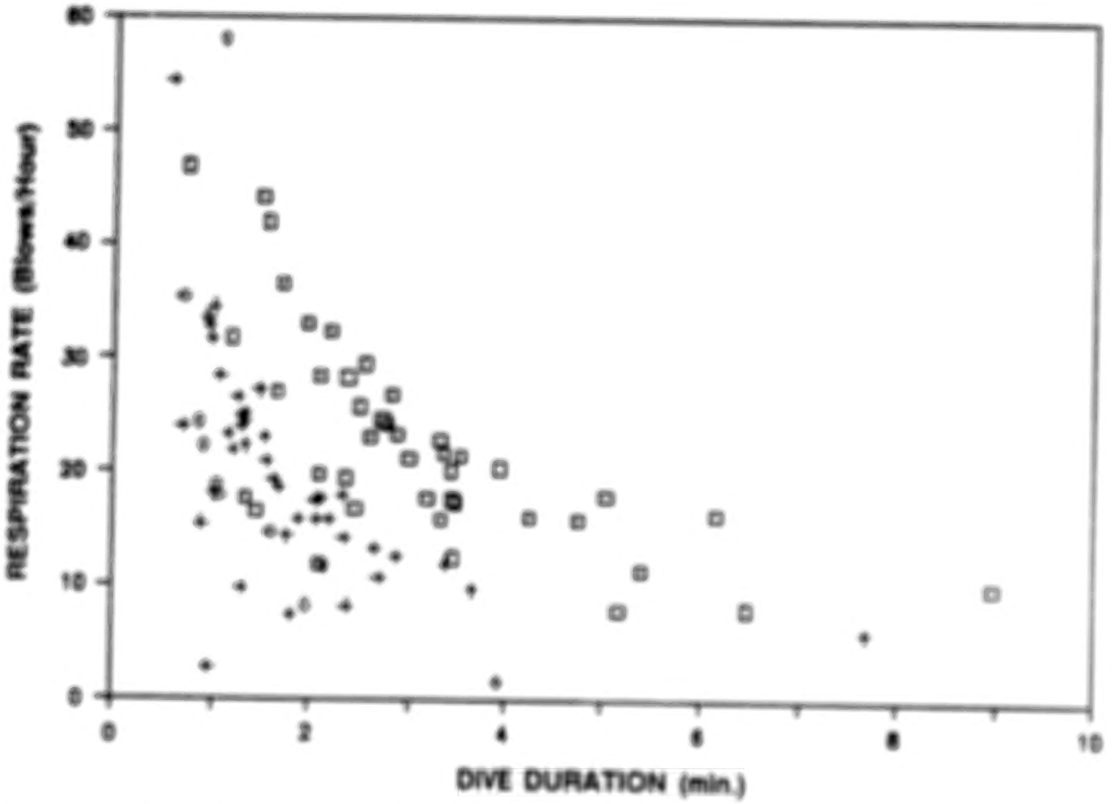


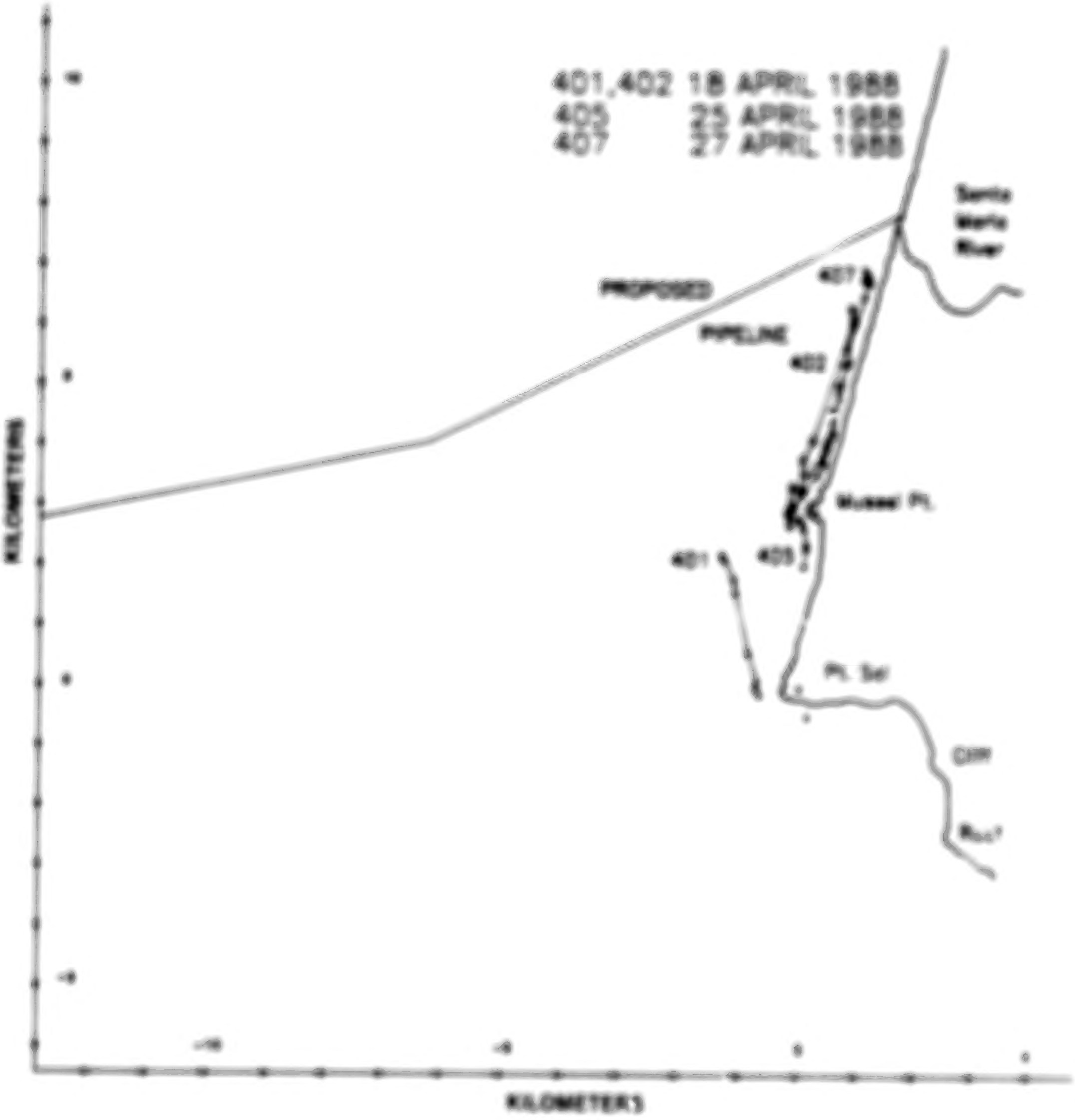
Appendix E-37. The relationship between dive duration and respiration rate of gray whales, northbound, Phase A migration.

Appendix E-38. A summary of gray whale behaviors, northbound, Phase A migration.

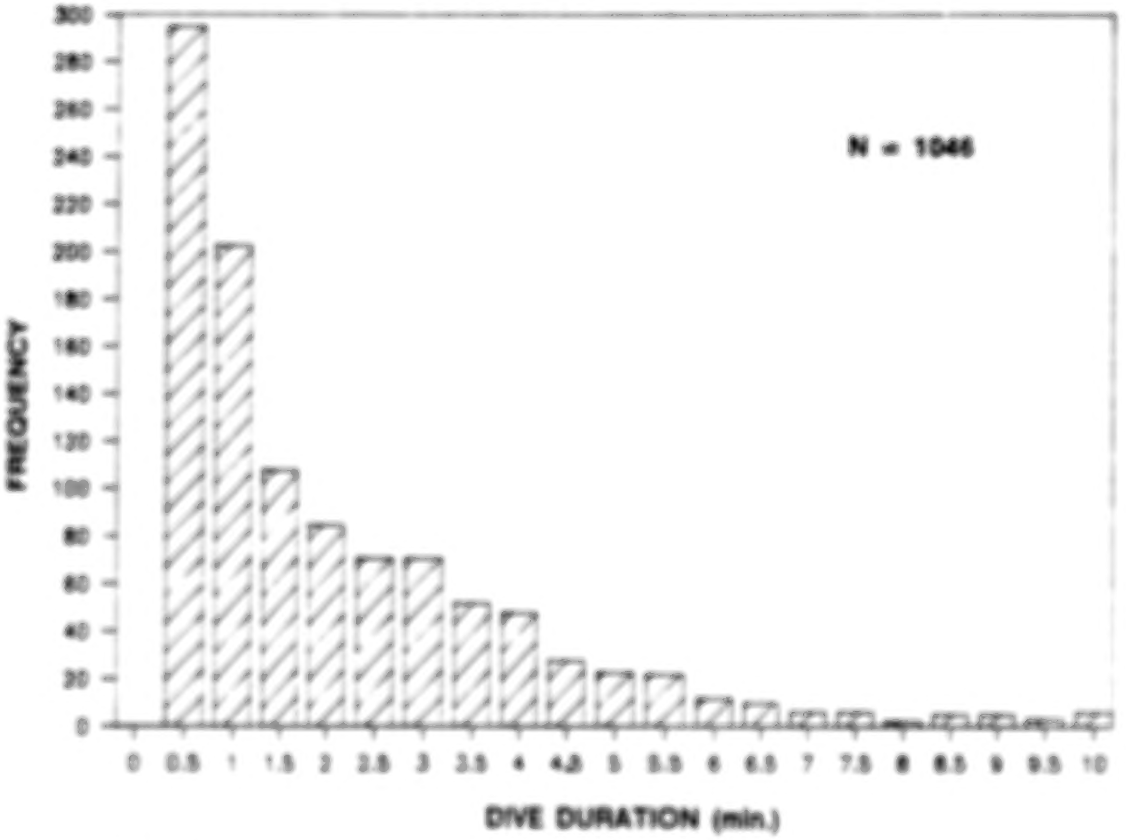
	April 1986		March 1987		March/April 1988	
	Total	% within Category	% Total	% within Category	Total	% within Category
Number of Days	6		6		15	
Number of Pods	1		29		131	
Total Observation Time (hrs)	40		31.2		98.4	
Traveling Mode						
Traveling	6	100.0	524	59.8	1232	81.8
Milling	0	0.0	352	40.2	275	18.2
Total	6	100.0	876	100.0	1507	100.0
Respiration						
Blows	6	100.0	910	97.8	1414	95.3
Surfacings, No Blows Observed	0	0.0	20	2.2	57	3.8
Total	6	100.0	930	100.0	1471	99.2
Surface/Social Behaviors						
No Apparent Behavior	6	100.0	528	59.1	1424	95.0
Breaching	0	0.0	11	1.2	16	1.1
Rolling	0	0.0	328	36.7	18	1.2
Headlift	0	0.0	8	0.9	22	1.5
Spyhop	0	0.0	3	0.3	3	0.2
Pod Splitting	0	0.0	2	0.2	1	0.1
Pods Joining	0	0.0	8	0.9	0	0.0
Tail Slap	0	0.0	3	0.3	0	0.0
Tail Lift	0	0.0	2	0.2	0	0.0
Vessel Avoidance	0	0.0	1	0.1	0	0.0
Total	6	100.0	894	100.0	1484	100.0
Diving Attitude						
Flukes Lifted	0	0.0	13	2.4	50	3.3
Flukes Not Lifted	6	100.0	531	97.6	1458	96.7
Total	6	100.0	544	100.0	1508	100.0

Appendix E-39. A summary of gray whale observations by pod size, number of individuals, and distance from shore, northbound, Phase B migration.

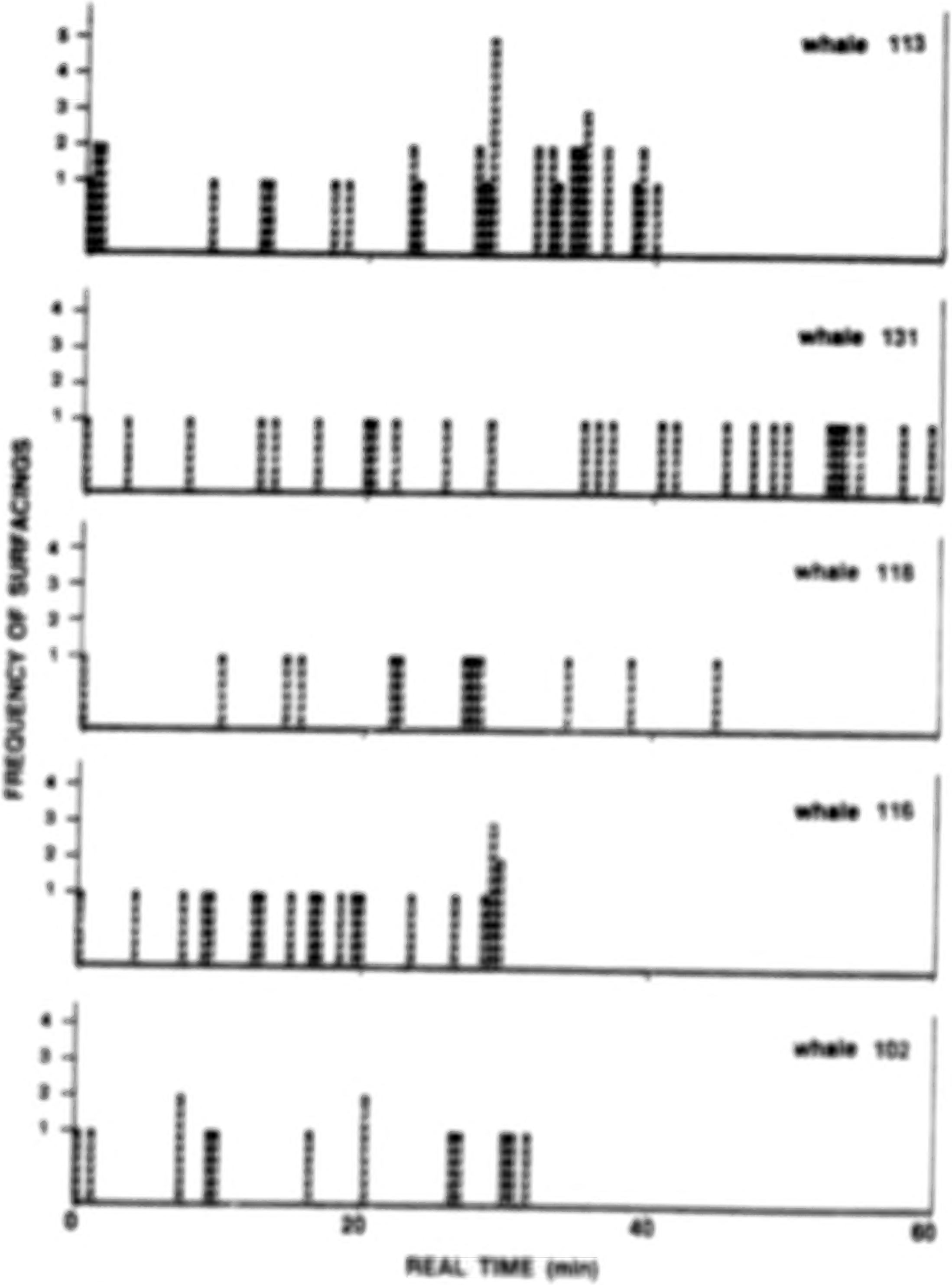
	Pods			Whales			
	n	Percent Frequency	Cumulative Frequency	n	Percent Frequency	Cumulative Frequency	Mean Pod Size
Distance (km)							
0-0.1	0	0.0	0.0	0	0.0	0.0	0
0.1-0.2	8	14.5	14.5	16	12.4	12.4	2.0
0.2-0.3	12	21.8	36.4	28	21.7	34.1	2.3
0.3-0.4	15	27.3	63.6	32	24.8	58.9	2.1
0.4-0.5	10	18.2	81.8	27	20.9	79.8	2.7
0.5-0.6	4	7.3	89.1	8	6.2	86.0	2.0
0.6-0.7	3	5.5	94.5	8	6.2	92.2	2.7
0.7-0.8	1	1.8	96.4	6	4.7	96.9	6.0
0.8-0.9	0	0.0	96.4	0	0.0	96.9	0.0
0.9-1.0	0	0.0	96.4	0	0.0	96.9	0.0
1.0-1.1	1	1.8	98.2	2	1.6	98.4	2.0
1.1-1.2	1	1.8	100.0	2	1.6	100.0	2.0
All Data	55	100.0		129	100.0		2.3



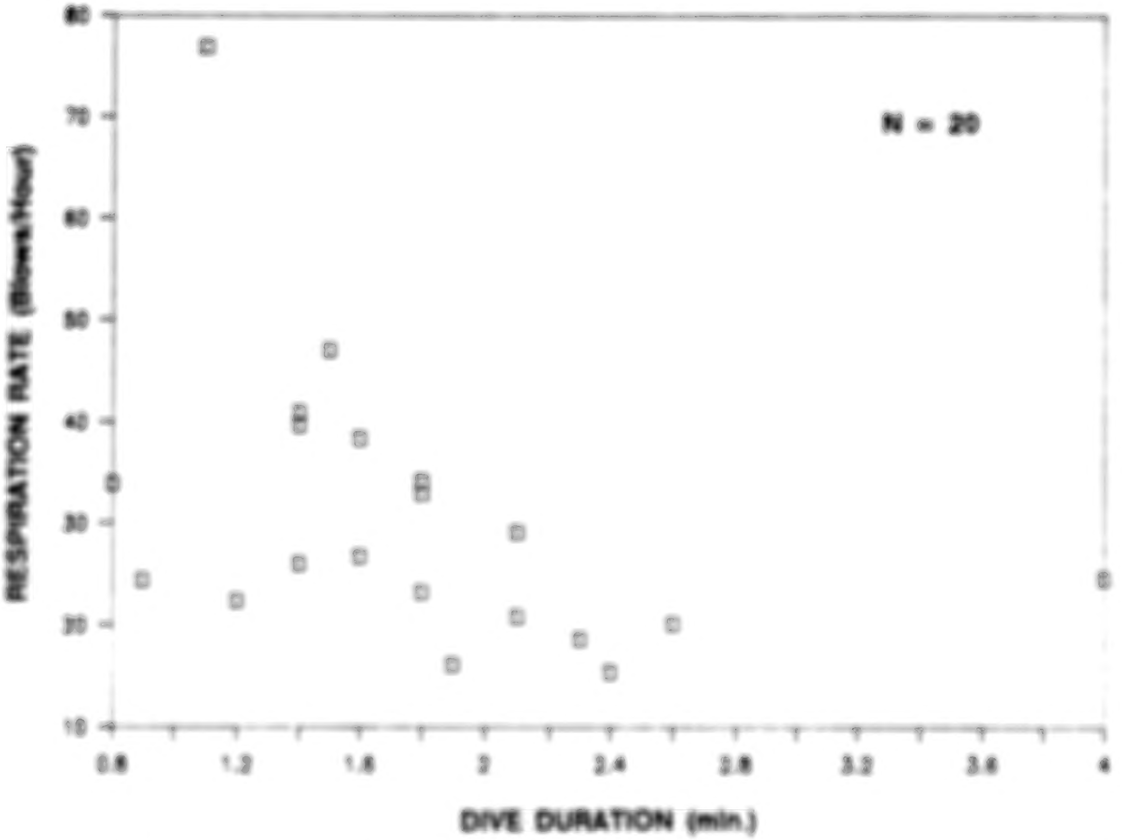
Appendix E-40. Routes taken by three gray whale pods, northbound, Phase B migration.



Appendix E-41. Frequency distribution of dive durations of gray whales, northbound, Phase B migration.



Appendix E-42. Surface-dive sequences of five pods of grey whales, northbound, Phase B migration.



Appendix E-43. The relationship between dive duration and respiration rate of gray whales, northbound, Phase B migration.

Appendix E-44. A summary of gray whale behavior, northbound, Phase B migration.

	Phase B 1986		Phase B 1988	
	Total	% within Category	Total	% within Category
Number of Days	8		6	
Number of Pods	46		6	
Total Observation Time (hrs)	40.0		34.2	
Traveling Mode				
Traveling	921	86.6	139	90.8
Milling	143	13.4	14	9.2
Total	1064	100.0	153	100.0
Respiration				
Blows	422	47.8	64	42.1
Blow Mother	101	11.4	22	14.5
Blow Calf	91	10.4	1	0.7
Blow Mother/Calf	61	6.9	0	0.0
Surfacings, No Blows Observed	207	23.4	65	42.8
Total	882	100.0	152	100.0
Surface/Social Behaviors				
No Apparent Behavior	830	78.6	125	81.2
Breaching	2	0.2	0	0.0
Rolling	13	1.2	4	2.6
Head Lift	1	0.1	1	0.6
Spyhop	6	0.6	0	0.0
Pod Splitting	9	0.9	0	0.0
Pod Joining	14	1.3	0	0.0
Calf Inside Mother	123	11.6	17	11.0
Calf Outside Mother	48	4.5	7	4.5
2 Calves/One Inside and Other Outside	6	0.6	0	0.0
Vessel Avoidance	0	0.0	0	0.0
Total	1056	100.0	154	100.0
Diving Attitude				
Flukes Lifted	2	0.2	0	0.0
Flukes Not Lifted	1067	99.8	136	100.0
Total	1069	100.0	136	100.0

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Appendix E-43. Incidental shorebased observations of marine mammals other than gray whales.

Species		Number	Date	Location/Behavior
Zalophus californianus *		1	26 Mar 87	Trav. south from Mussel Pt.
(California sea lion)		1	28 Mar 87	Just off Mussel Pt.
		4	29 Mar 87	Rafting just south of Mussel Pt.
		3	14 Mar 88	Trav. south, back to Lion Rock.
	Total	9		
Phoca vitulina		1	25 Mar 87	A few yards off rocks, off Mussel Pt.
(harbor seal)		1	26 Mar 87	In surf off Mussel Pt.
		1	29 Mar 87	Surf zone just south of Mussel Pt.
	Total	3		
Enhydra lutris		2	18 Jan 87	Feeding just north of Pt. Sal, 1/4 - 1/2 mi. offshore.
(sea otter)		1	16 Mar 87	Feeding off Pt. Sal.
		1	25 Mar 87	Trav. north from Mussel Pt.
		1	12 Mar 88	Feeding just north of Mussel Pt.
		1	18 Mar 88	Feeding between Pt. Sal and Mussel Pt.
	Total	6		
Balaenoptera acutorostrata (Minke whale)		1	18 Apr 88	Trav. north. One mile off Mussel Pt.
Delphinus delphis		100+	17 Mar 88	Trav. south. Five miles offshore.
(common dolphin)		100+	18 Mar 88	Trav. south. Five miles offshore.
	Total	200+		
Orcinus orca		12-15	25 Apr 88	Feeding. Two miles southwest of Pt. Sal.
(killer whale)		3	27 Apr 88	Trav. northeast. Three miles off Mussel Pt.
	Total	15-18		
Tursiops truncatus **		20	17 Jan 87	Trav. south, in surf, between Mussel Pt. and Pt. Sal.
(bottlenose dolphin)		10	20 Jan 87	Trav. south, surfed breakers at Pt. Sal.
		2	25 Mar 87	Trav. north, slowly.
		5	25 Mar 87	Surfing waves just north of Mussel Pt.
		12-15	11 Mar 88	Trav. south. Mussel Pt. - Pt. Sal.
		1	12 Mar 88	Trav. in close proximity to whale. Just north of Mussel Pt.
		4	14 Mar 88	Trav. north with whales. One mile north of Mussel Pt.
		6	16 Mar 88	Straight off Mussel Pt.
		3	18 Mar 88	Trav. south around Pt. Sal.
		20+	26 Apr 88	Trav. south from Mussel Pt. - Pt. Sal
		20+	27 Apr 88	With gray cow/calf pair and amongst surfers at Santa Maria River mouth.
	Total	85		
Dolphin, unid.		1	20 Jan 87	Possible Lags or common dolphin, 1/4 - 1/2 mi offshore

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* Not all sightings were recorded. Sea lions were always seen hauled out on Lion Rock.

** All _Tursiops truncatus_ were seen in, or just outside, the surf zone.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

END

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